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TRANSACTIONS.

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Read March 27, 1806.

Isle of France, Aug. 19, 1805.

A FORE-KNOWLEDGE of the wind and weather is an object so very interesting to all classes of men, and the changes in the mercurial barometer affording the means which appear most conducive to it, a system that should with certainty explain the connection between the variations of the mercury and those in the atmosphere under all circumstances, becomes greatly desirable; to seamen, more especially, whose safety and success depend so much upon being duly prepared for changes of wind, and the approaching storm, it would be an acquisition of the first importance: in a more extended view, I may say, that the patriot and the philanthropist must join with the philosopher and the mariner in desiring its completion. So long and widely-extended a course of observation, however, seems requisite to form even a basis for it, that a complete system is rather the object of anxious hope than of reasonable expectation. Much has been done towards it, but so much appears to remain, that any addition to the common stock, however small, or though devoid of philosophical accuracy, I have thought would be received by the learned with candour. With this prepossession, I venture to submit to them some observations upon the movement and state of the mercury upon the coasts of New Holland and New South Wales, the Terra Australis, or Australia, of the earlier charts.

The principal circumstance that has led me to think these observations worth some attention, is the coincidence that took place between the rising and falling of the mercury, and the setting in of winds that blew from the sea and from off the land, to which there seemed to be at least as much reference, as to the strength of the wind or state of the atmosphere; a circumstance that I do not know to have been before noticed. The immediate relation of the most material of these facts, it is probable, will be more acceptable than any prefatory hypothesis of mine; and to it, therefore, I proceed; only premising, that a reference to the chart of Australia will be necessary to the proper understanding of some of the examples.

My examination of the shores of this extensive country began at Cape Leuwen, and continued eastward along the south coast. In King GEORGE's Sound, December 20, 1801, after a gale from WSW, the mercury had risen from 29,42 to 29,84, and was nearly stationary for two days, the wind being then moderate at NW, with cloudy weather. On the 22d, the wind shifted to SW, blew fresh, and heavy showers of rain occasionally fell; but the mercury rose to 30,02, and remained at that height for thirty hours; and on the weather clearing up, and the wind becoming moderate in *the same quarter*, it rose to 30,28.

Fresh breezes from E and SE caused a rise in the barometer in King GEORGE's Sound, once to 30,20, and a second time to 30,18, although the weather at these times was hazy; but with light winds from the same direction, which were probably local sea breezes only, the mercury stood about 29,95 in that neighbourhood.

2d Example. Jan. 12, 1802, in D'ENTRECASTEAUX's Archipelago, the mercury rose to 30, 23, previously to a fresh breeze setting in from the eastward. In the evening of the 13th it blew strong from ESE, with hazy weather, and a rapid fall of the mercury to 29,94 had then taken place; but instead of the wind increasing, or bad weather coming on, the wind died away suddenly, and a light breeze came off the land at midnight, with cloudy weather.

At the Cape of Good Hope, which is nearly in the same latitude, the mercury rises with the fresh gales that blow there from the SE in the summer season. The weather that accompanies these south-east winds, is nearly similar in both places; the atmosphere being without clouds, but containing a whitish haze, and the air usually so dry as sensibly to affect the skin, particularly of the lips.

3d. Jan. 22. Three degrees east of the Archipelago, the mercury fell with some rapidity down to 29,65 with the wind from ESE. It was eight o'clock at night, and we prepared for a gale from that quarter; but at ten, the wind suddenly shifted to WNW, coming very light off the land. On its veering gradually round to SSW, clear of the land, at noon, 23d, it freshened, and the weather became thick; yet the mercury had then risen to 29,84, and at eight in the evening to 29,95, though the wind then blew strong. It continued to rise to 30,16 as the wind shifted round to SE, and fine weather came on; but on the wind passing round to ENE and NNE, which was off the land, the mercury fell back to 29,73, though the weather was fine and the wind moderate. On a sudden shift of wind to the SW, a fresh breeze with hazy weather, it again began to ascend, and a similar routine of wind, producing nearly the same effects upon the barometer, again took place. The effect of sea winds in raising the mercury, in opposition to a strong breeze, and of land winds in depressing it, though they were light, was here exemplified in two remarkable instances.

4th. In the neighbourhood of the Isle of St. FRANCIS of Nuyts, longitude 133¼° east of Greenwich, we experienced a considerable change in the barometer. For nine days in January and February the wind continued to blow constantly, though moderately, from the eastward, mostly from the SE. It appeared like a regular trade-wind or monsoon, but so far partook of the nature of sea and land breezes, as commonly to shift more to the southward in the day, and to blow more from east and NE in the night. The weather was very hazy during these nine days; so much so, that for six of them no observation of the sun's altitude, worthy of confidence, could be taken from the sea horizon, although the sun was sufficiently clear; and in the whole time, the mercury never once stood so high as 30 inches, but was frequently below 29,70. I considered this to be the more extraordinary, as settled winds from the eastward, and especially from SE, had before made it rise and stand high upon this coast, almost universally, even when there was a considerable degree of haze. The direction of the south coast, beyond the Isle of St. Francis, and even abreast of it, was at that time unknown to me; but I then suspected, from this change in the barometer, that we should find the shore trending to the southward, which proved to be the case. The easterly winds, then, whilst they came off the sea, caused the mercury to rise upon the south coast; but in this instance that they came from off the land, they produced a contrary effect; but it is to be observed, that the most hazy part of the time, and that during which the mercury stood lowest, was two days that the wind kept almost constantly on the north side of west, more directly off the land: its height was then between 29,65 and 29,60.

The haze did not immediately clear away on the wind shifting to the westward; notwithstanding which, and that the new wind rose to a strong breeze, and was accompanied with squalls of rain, the mercury began to ascend, and had reached 29,95 when the squalls of wind and rain were strongest; the direction of the wind being then from SSW. On its becoming moderate, between SSW and SSE, the mercury ascended to 30,14, and remained there as long as the wind was southwardly.

5th. Going up the largest of the two inlets on the south coast, in March, we were favoured with fine fresh breezes from SSW to SSE, sometimes with fine, sometimes with dull weather, the mercury rising gradually from 30,08 to 30,22. In twenty-four hours afterwards, it fell below 30 inches, and a light breeze came from the northward, off the land, with finer weather than before. The mercury continued to fall to 29,56, where it stopped; the wind having then ceased to blow steadily from the northward, and become variable. In twenty-four hours more, the wind set in again to blow fresh from the southward, the mercury having then returned to 29,94, and it was presently up to 30,22 and 30,28. It kept nearly at this height for several days that the southwardly wind blew fresh, but on its becoming lighter, and less steady in its direction, the mercury descended; and in the calm which followed, it had fallen to 29,90. This example affords clear proof of a fresh wind from the sea making the mercury rise, whilst a light wind off the land, with finer weather, caused it to descend.

6th. The calm was the prelude to a fresh gale; but the mercury began to rise at eight in the evening when it had just sprung up; by the next noon it was at 30,10 when the wind blew strongest, and in the evening at 30,22. This gale began as gales usually, if not always, do upon this coast, in the north-west quarter, and shifted round to SW and SSW; but quicker than I have generally seen them: there was no rain with it, nor was the atmosphere either very hazy or cloudy.* The mercury continued to rise till it had reached 30,25, and then was stationary as long as the wind remained between south and west; but on its veering round to the eastward of south, a second rise took place, and for forty hours the mercury stood as high as 30,45, the wind being then between SE by S and east: the weather was very dull and hazy during the first half of these forty hours, but finer afterwards. As the winds between SE by S and east slanted off the main land, this example seems to be in opposition to the 4th, and leads me to think, that it might have been the very extraordinary kind of haze, and perhaps some peculiarity in the interior part of the land abreast of the Isle of St. FRANCOIS that in part occasioned the fall of the mercury with south-east winds; as much, perhaps, as the circumstance of the wind coming from off the shore.

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* I afterwards learned from Captain BAUDIN, that this gale was much heavier in Bass' Strait than we felt it at Kanguroo Island.

After this rise in the mercury to 30,45, it fell gradually; but, for thirteen days, kept above 30 inches, the winds being generally between SE and SW, but light and variable, and the weather mostly fine.

7th. North-eastwardly winds, off the land, were the next that prevailed; they were light, and accompanied with cloudy weather and spitting rain. The mercury fell to 29,70, and remained there till the wind shifted to the west and southward, when it began to rise, and in two days was up to 30,42. At that time we were off the projection marked II in the chart, in 139½° east longitude; the wind had then veered to the south-eastward along the shore, with a steady breeze, and the mercury remained nearly stationary so long as it lasted; but on the wind dying off, and flawing from one side and the other, it descended quickly to 30 inches. A breeze then sprung up at NW, which, within twenty-four hours, shifted suddenly to SW, and blew a gale which had near proved fatal to us. It was accompanied with rain and very thick weather, and lasted two days; by which time, the mercury had descended to 29,58.

8th. In Bass' Strait, for several days in the month of April, the mercury stood above 30,40 with the wind from the south and eastward, sometimes blowing fresh: the weather generally fine. It then fell half an inch in eight hours, and a wind set in soon after from the north-westward which continued four days, blowing moderately, with cloudy weather, and sometimes a shower of rain; the mercury remaining stationary between 29,83 and 29,89. On this second wind dying away, a strong breeze sprung up which fixed at WSW with squally weather; but for three days no alteration took place in the barometer, until the wind shifted to NW and north, and the mercury then descended to 29,52, though the weather was finer, and wind more moderate than before.

9th. Passing along the south coast of Australia the second time, we experienced light winds from the sea for forty hours in D'ENTRECASTEAUX's Archipelago, in the month of May: they were variable between WSW and SSE with dull cloudy weather, and the mercury stood very high, being up to 30,50 most of the time. The wind then came round to N by E and NNW; previously to which, the mercury began to descend, and it kept falling for two days till it reached 30,19, though the weather was not so cloudy as before, and the wind was equally light. On the wind veering to west and WSW the mercury rose to 30,25; but it now came on to blow fresh, with squally thick weather, yet the mercury continued nearly stationary for twenty-four hours, appearing to be kept up in consequence of the wind having shifted round to SSW, more directly from off the sea. On its increasing to a gale, however, there was a pretty rapid descent in the barometer to 29,96; but the ascent again was equally rapid, and to a greater height, on the wind becoming moderate. In a short calm that succeeded, the mercury stood at 30,42, but on the wind setting in from the north, which was from off the land, it fell to 30,25, and remained there two days: we had then reached Bass' Strait.

From these examples upon the south coast, it appears, generally, that a change of wind from the northern, to any point in the southern half of the compass, caused the mercury to rise, and a contrary change to fall; and that the mercury stood considerably higher when the wind was from the south side of east and west, than, in similar weather, it did when the wind came from the north side; but, until it is known what are the winds that occasioned the mercury to ascend, and what to descend, upon the other coasts of Australia, it will probably be not agreed, whether it rose in consequence of the south winds bringing in a more dense air from the polar regions, and fell on its being displaced by that which came from the Tropic;—or whether the rise and higher standard of the mercury was wholly, or in part, occasioned by the first being sea winds, and the descent because those from the northward came from off the land.

The height, at which the mercury generally stood upon the south coast, seems to deserve some attention. It was very seldom down to 29,40, and only once to 29,42. Of one hundred and sixty days, from the beginning of December to May, it was nearly one-third of the time above 30 inches; and the second time of passing along the coast, from the 15th of May to the 1st of June, it only once descended to 29,96, and that for a few hours only, its average standard for these sixteen days being 30,25. Upon the eastern half of the coast, beyond Cape Catastrophé, in March, April, and May, the mercury stood higher than it did on the western half in December, January, and February: the average standard of the first was 30,09, but that of the latter only 29,94. At the Cape of Good Hope, the mean height in the barometer, during eighteen days in October and November, was 30,07.

The marine barometer on board the Investigator, supplied to the astronomer by the Board of Longitude, was made by NAIRNE and BLUNT, and had, I believe, been employed in one or more of the voyages of Captain COOK, and perhaps in that of Captain VANCOUVER. I suspect, that it was not suspended so exactly in the proper place, as the later instruments of these makers probably are; on which account, the motion of the ship caused the mercury to stand too high; and perhaps one or two-tenths of an inch might be deducted with advantage from the heights taken at sea, but I think not when the ship was lying steadily at anchor in harbour. The barometer stood in my cabin, and the height of the mercury was taken at day-break, at noon, and at eight in the evening, by the officer of the watch; as was also that of the thermometer.

The general effects produced upon the barometer by the sea and land winds, on the east coast of Australia, will be learned from the following abridgment of our meteorological journal.

1st. In the run from Cape HOWE, in 37½° south latitude, to Port Jackson, in 34°, once in the month of May, and once in June, I found that the mercury descended with light winds from north, NW, west, and WSW; whilst during fresh breezes from south and SW it ascended, and stood considerably above 30 inches; with the wind at NE and NNE it also kept above 30 inches, but not so high, nor did it rise so fast, as when the wind was from SSW. From between south and east, the winds did not blow during these times. This example does not differ so much from those on the south coast as to be decisive of any thing.

2d. The observations made during a stay of ten weeks at Port Jackson, in May, June, and July, 1802, are more in point than almost any other. Strong eastwardly winds were very prevalent at that time, and were almost always accompanied with rain and squalls; yet this weather was foretold and accompanied by a rise in the barometer, and the general height of the mercury during their continuance was 30,20: higher if the wind was on the south side of ESE, and lower if on the north side of east. The winds from south and SSW, which blow along the shore, kept the mercury up to about 30,10, when they were attended with fine weather, as they generally were; but if the weather was squally, with rain, it stood about 29,95. During settled winds from between WNW and SW, with fine weather, the mercury generally stood very low, down at 29,60;* and what is more extraordinary, when these winds were less settled, and the weather dull, with rain occasionally falling, the range of the mercury was usually between 29,80 and 30,10; nearly the same as when the wind was at SSW with similar weather; the reason of which may probably be, that at some distance to the southward these westwardly winds blew more from the south, and were turned out of their course, either by the mountains, or by meeting with a north-west wind farther to the northward.

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* My friend Colonel PATERSON, F. R. S. commander of the troops at Port Jackson, in judging of the approaching weather by the rise and fall in his barometer in the winter season, told me, that he had adopted a rule directly the reverse of the common scale. When the mercury rose high, he was seldom disappointed in his expectation of rainy, bad weather; and when it fell unusually low, he expected a continuance of fine, clear weather, with westwardly winds.

The winds from north and NW blew very seldom at this time: the mercury fell on their approach.

To the state of the mercury during our second stay at Port Jackson, in July, 1803, and part of June and August, it is not in my power to refer, as I have not been able to obtain that part of my journal from General DE CAËN.

The effects of some winds upon the barometer in this 2d example, are considerably different to what they were upon the south coast. The wind at WSW or SW with fine weather, had always caused the mercury to rise and stand high, and those from the NE to fall; whereas here, the effects of those winds were almost directly the reverse. The winds from SSW, SE, and as far as east, made it rise on both coasts, with the exception of the 4th example on the south; and from between north and WNW the mercury fell in both cases and stood low.

3d. Steering along the east coast, from Port Jackson to the northward, in July, we had the winds usually between south and SW, and sometimes WSW, the mercury being nearly stationary at 30 inches; but meeting with a spurt of the south-east trade wind in latitude 24°, we found it rise to 30,30 for two days. A westwardly wind brought it back to 30 inches for a short time; but on the trade wind finally setting in, it fixed itself between 30,20 and 30,30, as long as the wind preserved its true direction.

4th. The month of September, 1802, and the greater part of August and October, we spent upon the east coast between the latitudes 23° and 17°. The south-east trade is the regular wind here, but we had many variations. Whilst the trade prevailed, the average standard of the mercury was 30,15, and the more southwardly it was, and the fresher it blew, the higher the quicksilver rose, though it never exceeded 30,30. When the trade wind was light, it was usual for a breeze to come off the land very early in the morning, and continue till eight or nine o'clock; but these temporary land winds did not produce any alteration in the mercury, which kept at these times about 30,10. When the trade wind veered round to ENE, or more northward, which was not seldom, the mercury ranged between 30 inches and 30,10; and when a breeze from north or N by W prevailed, which was the case for a considerable part of twenty days we remained in Broad Sound, its height was something, but not much, less. These northwardly winds I take to have been the north-east wind in the offing; which had been partly turned, and in part drawn out of its direction, by the peculiar formation of this part of the east coast. There are but few instances of any steady westwardly wind prevailing; when such happened, they were generally from the north side of west; and at these times the range of mercury was between 29,95 and 30,05, which was the lowest I at any time saw it on this portion of the east coast.

The barometer was of great service to me in the investigation of this dangerous part of the east coast, where the ship was commonly surrounded with rocks, shoals, islands, or coral reefs. Near the main land, if the sea breeze was dying off at night, and the mercury descending, I made no scruple of anchoring near the shore; knowing that it would either be a calm, or a wind would come off the land; but if the mercury kept up, I stretched off, in the expectation that it would freshen up again in a few hours. Amongst the barrier reefs, when the wind was dying away, the barometer told me, almost certainly, from what quarter it would next spring up. If the mercury stood at 30,15, or near it and was rising, I expected the proper trade wind; and if higher, that it would be well from the southward, or would blow fresh; and if it was up to 30,30, both. The falling of the mercury to 30,10 was an indication of a breeze from the north-eastward; and its descent below 30 inches that it would spring up, or shift round to the westward. This regularity of connection between the barometer and the direction of the wind, is perhaps too great to be expected at a different time of the year; and it is probable, that we should not have found it continue so strictly, had our stay amongst the barrier reefs been much prolonged.

5th. Leaving the east coast in the latitude 17° south, we steered off to the northward for Torres' Strait, in the latter part of October. As we advanced northward, I found the mercury stand gradually lower with the same kind of wind and weather. The difference was not material till we reached the latitude 13°, but afterwards, the south-east wind which had before kept the mercury up to 30,15, then permitted it to fall to 29,90; and the winds from ENE and NNE to 29,85. Was this alteration owing to the want of density in the air brought in by the south-east winds, in this lower latitude?—to our increased distance from the land?—or was it, that the south-east wind was no longer obstructed by the coast, having a passage there through Torres' Strait?

The difference between the height of the mercury, during a north-east and a south-east wind, was much less here than before, although the weather was most unfavourable during the time of the north-east wind, and should have increased the difference in their effects. Was this owing to the general approximation to that equality which has been observed to take place in the barometer, in very low latitudes?—or that the north-east wind, still meeting with resistance from the coast, had one cause for keeping up its power, which the south-east wind had lost?

In a general summary of the winds on the east coast, those that came from between south and east caused the mercury to rise and stand highest, as they had also done upon the south-coast, with the exception of the 4th example. The winds from NE kept the mercury up above 30 inches on the east coast, and caused it to rise after all other winds except those from the south-eastward; but on the south coast, the mercury fell with them, and stood considerably below 30 inches; because, as it appears to me, they then came from off the land. During north-west winds, the mercury stood lower than at any other time upon both coasts; and on both they came from off the land.

Moderate winds from the south-westward, with fine weather, caused a descent of the mercury on the east coast; and during their continuance it was much lower than with winds from the north-eastward; but upon the south coast it rose with south-west winds, and stood much higher than when they came from the opposite quarter. For this change I cannot see any other reason, than that the wind, which blew from the sea upon one coast, came from off the land in the other.

Although the height of the mercury upon the south coast of Australia was, upon the average, considerably above the medium standard 29,50, it was still greater upon the east coast: I cannot fix it at less than 30,08 or 30,10, whereas upon the south coast, I should take it at 30 inches; both subject to the probable error of one or two-tenths of an inch in excess. This superiority seems attributable to the greater prevalence of sea winds upon the east coast, and particularly of those from SE, which, *when all other circumstances are equal*, I have observed to raise the mercury higher than any other on this side of the equator, analogous to the effect of north-east winds in the northern hemisphere; and perhaps also, the superiority may be in part owing to the east coast having a more regular chain of higher mountains running at the back of, and parallel to it, which presents a greater obstruction to the passage of the wind over the land, than it meets on the south coast.

The greatest range of the mercury observed upon the east coast, was from 29,60 to 30,36 at Port Jackson; and within the tropic from 29,88 to 30,30; whilst upon the south coast, the range was from 29,42 to 30,51, in the western part, where the latitude very little exceeds that of Port Jackson. It is to be observed, however, that these extremes are taken for very short intervals of time.

My observations upon the north coast of Australia are but little satisfactory, both because the changes in the barometer were very small in so low a latitude, and that very little more than the shores of the gulph of Carpentaria could be examined, on account of the decayed state of the Investigator, which obliged me to return with all practicable expedition to Port Jackson. An abridged statement, however, of the general height of the mercury under the five following circumstances, will afford some light upon the subject, and perhaps not be uninteresting. 1st. On the east side of the gulph, and at the head, with the south-east monsoon, or trade wind. 2d. At the head of the gulph with the north-west monsoon. 3d. On the west side during the north-west monsoon. 4th. At Cape Arnhem under the same circumstance; and 5th. In the passage from Cape Arnhem, at a distance from the coast, to Timor, with variable winds.

In a memoir written by ALEXANDER DALRYMPLE, Esq. F.R.S. respecting the Investigator's voyage, there is this general remark:—"Within the tropics, the monsoon blowing "on the coast produces rainy weather, and when blowing "from over the land, it produces land and sea breezes." This I found verified on the east side of the gulph of Carpentaria, between Nov. 3 and 16, which time was employed in its examination; for though we had found the south-east trade to blow constantly on the east side of Cape York just before, and doubtless it did so then, yet in the gulph we had a tolerably regular sea breeze, which set in from the westward at eleven or twelve o'clock, and continued till seven, eight, or nine in the evening. Towards the head of the gulph, the trade wind, which blew at night and in the morning, came more from the NE, and the sea breezes more from north and NW, but without producing any regular alteration in the height of the mercury, whose average standard was 29,95: it never fell below 29,90 or rose above 30,04. At the head, the height of the mercury remained nearly the same, until the north-west monsoon began to blow steadily, about the 10th of December, two or three days excepted, when the day winds were from the south-eastward, and the mercury then stood between 29,80 and 29,85. At these times, however, there was usually some thunder and lightning about, signs of the approaching rainy monsoon, which may perhaps account for the descent of the mercury independently of the direction of the wind.

2d. On the confirmation of the north-west monsoon, there was a change in the barometer at the head of the gulph, the common standard of the mercury being at 29,88; but during the times of heavy rain, with thunder, lightning, and squalls of wind, when amongst the islands of Cape Vanderlin, the mean height was 29,79. The north-west monsoon, after coming over Arnhem's land, blows along the shore for a considerable part of the space between the Cape Maria and Cape Van Diemen, of Tasman; and during the examination of the parts so circumstanced, we sometimes had tolerably fine weather, and the mercury above 29,90; but the wind was then usually more from the north than when the mercury stood lower. As we approached Cape Maria, and the bight between it and the south side of Groote Eyland, the mercury stood gradually lower; and in the bight, where the north-west monsoon came directly from off the shore, although we had sea and land breezes, with fine weather, according to Mr. Dalrymple's general position, yet the mercury was uncommonly low, its range being from 29,63 to 29,81: the average 29,74, below what it had stood in the very bad weather near Cape Vanderlin. These winds and weather, and the low state of the mercury, continued until we got without side of Groote Eyland.

3d. On the east side of Groote Eyland, and the west side of the gulph, northward from that island, we sometimes had sea and land breezes with fine weather; we had also two moderate gales of wind from the eastward, of from two to four days continuance each, with one of which there were heavy squalls of wind and rain; sometimes also, the winds were tolerably steady between north and west, with fine weather. During all these variations, the mercury never differed much from its average standard 29,90; and it seemed as if the increase of density in the air, from the wind blowing upon the coast, was equal to its diminution of quantity from the fall of rain and strength of the wind; and on the other side, that the wind from over that corner of Arnhem's Land permitted the mercury to descend, as much as the fine weather would otherwise have occasioned it to rise.

Upon the north side of Groote Eyland, the mercury stood higher than usual for five days, and during this time the wind blew with more regularity from NW, the only exception being for a few hours in the afternoons, when it commonly sprung up from the NE in the manner of a sea breeze: the weather remained fine during these five days, and the height of the mercury averaged 29,94.

4th. In the neighbourhood of Cape Arnhem, the mercury usually stood about 29,90, whether the wind was from NW, NE, or east, if the weather was fine; but if by chance the wind shifted to the south side of west, off the land, it descended to 29,80 though the weather remained the same; and this was its standard during those times when strong gusts came from the NW accompanied with heavy rain, thunder, and lightning.

In this example, the wind from SW occasioned the mercury to stand lower than that from NW in the same weather; which is contrary to what was observed upon the south and east coasts; particularly on the former, where the south-west wind elevated the mercury up to, and sometimes above, 30,25.

5th. On March 6, 1803, we made sail off from the north coast, towards Timor, the north-west monsoon having ceased to blow at Cape Arnhem, and the eastwardly winds appearing to have set in; but we soon outran them, and had the wind so variable and light afterwards, that it took us twenty-three days to reach Coepang Bay, a distance of no more than 12° of longitude. The only two remarks I made upon the barometer during this passage were, that the common height of the mercury was 29,95 at those times that the wind remained steady for some hours, from whatever quarter it came, and about 29,85 when it was most unsettled; and that it stood higher, upon the average, after we had passed Cape Van Diemen, when the south-west winds, which blew oftenest, came from the sea, than it did before.

The medium height of the mercury, deducting the time between Cape Maria and Groote Eyland in the 2d example, I should take at 29,92, which, when the quantity of rainy squally weather, with thunder and lightning, is considered, is very high: the whole range of the mercury upon the north coast was four-tenths of an inch.

The principal differences in the effect of winds upon this coast, from what they produced upon the south and east coasts, are, that a north-east wind raised the mercury as high, if not higher, than one from the SE; and that a north-west wind, where it came from off the sea and was moderate, was equal to either of them, and kept it up higher than the south-west wind did.

In order to have ascertained the full effects of sea and land winds upon the barometer, it was desirable to have learned, whether the south-east winds, which occasioned the mercury to rise highest upon the south and east coasts, would have left it at the medium standard, or made it descend upon the north-west and west coasts of Australia; but, unfortunately, the state of the ship did not permit me to determine this; for at the distance we kept from these coasts, in making the best of our way to Port Jackson, the accumulation of air over the shore, arising from a sea wind, or the contrary from a land wind, can scarcely be supposed to have much, if any effect. The principal winds we experienced between Timor and Cape Leuwen, in the months of April and May, were from SE and SW. The south-east wind prevailed as far as the latitude 25°, and the mercury stood at first with it at 29,95; but as we advanced southward, it rose gradually to 30,25, nearly in the same way as it had before descended on the east side of Australia, when we steered northward in the month of October. This wind was succeeded by an unsteady northwardly wind, which brought the mercury down to 29,90; but on its veering by the west to SW it rose fast, and fixed itself about 30,32: we were then drawing near Cape Leuwen.

As far as this example can be admitted in proof, it appears, that a wind from the SW has an equal, if not a superior power to one at SE in raising the mercury upon the west coast; which was not the case upon the south, and still much less upon the east and north coasts, where the south-west wind caused it to fall. Winds from the northward caused the mercury to descend, as I believe they always will in the southern hemisphere, if not obstructed by the land; but upon the north coast, we have seen the mercury stand higher with it than almost any other.

Upon a summary of the effects of the same winds upon the different coasts of Australia, as deduced from the above examples, the following queries seem to present themselves.

Why do the winds from north and NW, which cause the mercury to descend and stand lower than any other upon the south and east coasts, as also in the open sea, and in the south-west bight of the gulph of Carpentaria, make it rise upon the outer part of the north coast, with the same, or even worse weather?

Why should the north-east wind, which occasions a fall in the barometer upon the south coast, considerably below the mean standard, be attended with a rise above the mean upon the east and north coasts?

The south-east wind, upon the south and east coasts, caused the mercury to rise higher than any other; why should it not have the same effect upon the north coast, and upon the west?

How is it that the south-west wind should make the quicksilver rise and stand high upon the south and west coasts,—should cause it to fall much below the mean standard upon the east coast,—and upon the north, make it descend lower than any other, with the same weather?

The answer, I think, can only be one; and it seems to be sufficiently obvious.

The cause of the sensibility of the mercury to winds blowing from the sea and from off the land, may perhaps admit of more than one explanation; but the following seems to me to be direct, and tolerably satisfactory. The lower air, when brought in by a wind from the sea, meets with resistance in passing over the land; and to overcome this resistance, it is obliged to rise, and will make itself room by forcing the superincumbent air upwards. The first body of air, that thus comes in from the sea, being itself obstructed in its velocity, will obstruct the second, which will therefore rise over the first in like manner, to overcome the obstruction; and as the course of the second body of air will be more direct towards the top of the highest part of the land it has to surmount, than the first was, so the first part of the second body will arrive at the top, before the latter part of the first body has reached it; and this latter part will not be able to pass over the top, being kept down by the second body and the successive stream of air, whose velocity is superior to it. In this manner, an eddy, or body of compressed, and comparatively inactive air will be formed, which, at first, will occupy all the space below a line drawn from the shore to the top of the highest land; but, almost immediately, the succeeding bodies of air, at a distance from the shore, will feel the effect of the obstruction; and being impelled by those that follow them, will begin to rise, taking their course for the top of the highest land, before they come to the shore; by which means, the stratum of lower air will be deeper between the top of the land and the shore, and to some distance out from it, than it is either upon the mountains or in the open sea. If this is admitted to be a necessary consequence of a wind blowing upon the shore from the sea, it follows, that the mercury ought to stand something higher when such a wind blows, whether it is from the south or any other quarter, than it will with the same wind where it meets no such obstruction; and the more direct it blows upon the coast, and the higher the land is, (all other circumstances being equal,) the higher ought the mercury to rise. On the other hand, when the wind comes from off the hills, this dead and dense air will be displaced, even from its hollows under the highest land; both on account of its own expansion, and because its particles will be attracted by those of the air immediately above, which are taking their unobstructed course out to sea; and thus the air over the coast will resume its natural state with a land wind.

In order to appreciate duly the effect of sea and land winds upon the barometer, in the preceding examples, it is necessary to be recollected, that in the southern hemisphere, a wind from the south has a natural tendency to raise the mercury in the open sea, and one from the north to depress it; probably, from the superior density of the air brought in by the former; therefore, if the mercury rises quicker and higher with a south wind upon the south coast, than it does with a north wind upon the north, it is not to be at once concluded, that the effect of the wind as coming from the sea, is less upon the north coast; for it has, in the first place, to counteract the tendency of the mercury to fall with a north wind; and in some cases, its effects as a sea wind may be as considerable, relatively to the latitude, where there shall be no rise in the barometer, as upon the south coast it might where a considerable one took place. The same thing may be said of the winds from the east and from the west; for where the vicinity of land is out of the question, the former generally causes an ascent, (from what principle I leave others to determine,) and the latter a descent in the barometer, and I believe this extends to both hemispheres, and all climates. The wind from SE then, which combines something more than half the power, both of the south and of the east wind, will raise the mercury higher than any other, on the south side of the equator, and the wind from NW permit it to fall lower, independently of their effects as sea and land winds; and this allowance requires to be first made upon them: the south-west and north-east quarters should be equal where there is no land in question, and of a medium strength between the power of the south-east, and the deficiency of the north-west wind.

I leave it wholly undetermined, whether the effects of sea and land winds upon the barometer, as above described, extend beyond the shores of the country where these observations were made, and to about one hundred leagues of distance from them; but it seems not improbable, that they may be found to take place near the shores of all countries similarly circumstanced; that is, upon those which are wholly, or for the most part, surrounded by the sea, and situated within the fortieth degree of latitude. In colder climates, where snow lies upon the ground during a part of the year, the wind from off the land may perhaps be so cold, and the air so much condensed, as to produce a contrary effect; but this, and the prosecution of the subject to other important consequences, I leave to the philosopher; my aim being only to supply my small contribution of raw materials to the hands of the manufacturer, happy if he can make them subservient to the promotion of meteorological science.

I will conclude with stating a few general remarks upon the barometer, such as may be useful to seamen.

It is not so much the absolute, as the relative height of the mercury, and its state of rising and falling, that is to be attended to in forming a judgment of the weather that will succeed; for it appears to stand at different heights, with the same wind and weather, in different latitudes.

In the open sea, it seems to be the changes in the weather, and in the strength of the wind, that principally affect the barometer; but near the shore, a change in the direction of the wind seems to affect it full as much, or more, than either of those causes taken singly.

It is upon the south and east coasts of any country in the southern, or the north and east coasts in the northern hemisphere, where the effect of sea and land winds upon the barometer is likely to be the most conspicuous.

In the open sea, the mercury seems to stand higher in a steady breeze of several days continuance, from whatever quarter it comes, provided it does not blow hard, than when the wind is variable from one part of the compass to another; and perhaps it is on this account, as well as from the direction of the wind, that the mercury stands higher within the tropics, than, upon the average, it appears to do in those parallels where the winds are variable and occasionally blow with violence.

The barometer seems capable of affording so much assistance to the commander of a ship, in warning him of the approach and termination of bad weather, and of changes in the direction of the wind, even in the present state of meteorological knowledge, that no officer in a long voyage should be without one. Some experience is required to understand its language, and it will always be necessary to compare the state of the mercury with the appearance of the weather, before its prognostications will commonly be understood; for a rise may foretel an abatement of wind,—a change in its direction,—or the return of fine weather; or if the wind is light and variable, it may foretel its increase to a steady breeze, especially if there is any easting in it; and a fall may prognosticate a strong breeze or gale, a change of wind, the approach of rain, or the dying away of a steady breeze. Most seamen are tolerably good judges of the appearance of the weather; and this judgment, assisted by observation upon the quick or slower rising or falling of the mercury, and upon its relative height, will in most cases enable them to fix upon which of these changes are about to take place, and to what extent, where there is only one; but a combination of changes will be found more difficult, especially where the effect of one upon the barometer is counteracted by the other; as for instance, the alteration of a moderate breeze from the westward with dull, or rainy weather, to a fresh breeze from the eastward with fine weather, may not cause any alteration in the height of the mercury; though I think there would usually be some rise in this case. Many combinations of changes might be mentioned, in which no alteration in the barometer would be expected, as a little consideration, or experience in the use of this instrument, will make sufficiently evident; the barometer alone, therefore, is not sufficient; but in assisting the judgment of the seaman, is capable of rendering very important services to navigation.

XI. *Account of a Discovery of native Minium. In a Letter from* James Smithson, *Esq. F. R. S. to the Right Hon. Sir* Joseph Banks, *K. B. P. R. S.*

Read April 24, 1806.

MY DEAR SIR,

I BEG leave to acquaint you with a discovery which I have lately made, as it adds a new, and perhaps it may be thought an interesting, species to the ores of lead. I have found *minium* native in the earth.

It is disseminated in small quantity, in the substance of a compact carbonate of zinc.

Its appearance in general is that of a matter in a pulverulent state, but in places it shows to a lens a flaky and crystalline texture.

Its colour is like that of factitious minium, a vivid red with a cast of yellow.

Gently heated at the blowpipe it assumes a darker colour, but on cooling it returns to its original red. At a stronger heat it melts to litharge. On the charcoal it reduces to lead.

In dilute white acid of nitre, it becomes of a coffee colour. On the addition of a little sugar, this brown calx dissolves, and produces a colourless solution.

By putting it into marine acid with a little leaf gold, the gold is soon intirely dissolved.

When it is inclosed in a small bottle with marine acid, and a little bit of paper tinged by turnsol is fixed to the cork, the paper in a short time entirely loses its blue colour, and becomes white. A strip of common blue paper, whose colouring matter is indigo, placed in the same situation undergoes the same change.

The very small quantity which I possess of this ore, and the manner in which it is scattered amongst another substance, and blended with it, have not allowed of more qualities being determined, but I apprehend these to be sufficient to establish its nature.

This native minium seems to be produced by the decay of a galena, which I suspect to be itself a secondary production from the metallization of white carbonate of lead by hepatic gas. This is particularly evident in a specimen of this ore which I mean to send to Mr. GREVILLE, as soon as I can find an opportunity. In one part of it there is a cluster of large crystals. Having broken one of these, it proved to be converted into minium to a considerable thickness, while its centre is still galena.

I am, &c.

JAMES SMITHSON.

Cassell in Hesse,
March 2d, 1806.

XII. *Description of a rare Species of Worm Shells, discovered at an Island lying off the North-west Coast of the Island of Sumatra, in the East Indies. By* J. Griffiths, *Esq. Communicated by the Right Hon. Sir* Joseph Banks, *K. B. P. R. S.*

Read February 13, 1806.

A short time after a very violent earthquake that occurred in the island of Sumatra, in the year 1797, these uncommon productions of nature were discovered; the violence of the concussion was more particularly confined to that part of the island situated on the sea coast, between two degrees of the equator north and south, and to the islands adjacent. Its effects were most severely felt at Padang; many lives were lost, and considerable damage sustained, by a most tremendous inundation of the sea; this was also experienced at the low island of Battoo, distant from the coast of Sumatra about twenty leagues.

These shells were procured in a small sheltered bay, with a muddy bottom, surrounded by coral reefs, on the island of Battoo; upon the sea receding from the bay after the inundation they were seen protruding from a bank of slightly-indurated mud, and two or three broken specimens were brought to me at Padang, by the master of a boat trading between that port and the island, for cocoa-nut oil, sea slug, &c.

As I had not observed any of these shells in the cabinets I had seen abroad, or in England, nor yet a description in any author that I was able to consult, joined to the total ignorance of the Dutch inhabitants of Padang, many of whom had been a long time in the habit of trading to Battoo without having seen or heard of such a production, led me to believe them entirely new, and made me extremely desirous to procure some more perfect specimens, and such information respecting them, as might be acceptable to you, Sir, in your pursuit and inquiry on every subject connected with natural history.

I was consequently induced to send a small praw, with a servant of mine (a Papooa Coffree) who was very expert in diving, and had been employed under my own inspection in procuring many submarine objects, which the coast and islands near Padang abound with; it is therefore from his account, corroborated by others of the crew, that I can give a description of the locality of these subjects, with their appearance in the water, which I think is correct.

He stated, that he had found these tube shells in the bay before mentioned, and in another inlet of the sea, sticking out of rather hard mud, mixed with small stones, sand, &c. from eight to ten inches or more, and from one to three fathoms under water; they were standing in different directions, and separate from each other. Both the master of the boat and crew assured me, that the animal throws out tentacula from the two apertures of the apex of the shell, that resembled the small actiniæ adhering to the rocks about Padang, and that the body of the shell was filled with a soft gelatinous flesh, similar to that of the teredo navalis, but this they had washed out, from its very soon proving putrid, and extremely offensive; that they were in considerable number, and being gently shaken, easily taken up; but all of them mutilated more or less, which was probably occasioned at the time of the earthquake, when many large fragments of madrepores, corals, &c. were torn from their situation, by the agitation of the sea.

Although more than twenty specimens were brought to me, and others obtained afterwards, there was not one complete; yet being so fortunate as to procure a portion of the shell with the apex nearly perfect, and another with the opposite closed extremity equally so, I am enabled to give a description of them.

The length of the longest of these shells that came into my possession was 5 feet 4 inches, and the circumference at the base 9 inches, tapering upwards to 2½ inches; the colour on the outside milk white, the inner surface rather of a yellow tinge. This specimen was nearly perfect, having a small part of the lower extremity entire. I have others of various dimensions, a very good one about 3 feet long and 4 inches round, tapering to 1½ inch at the point; most of these shells had adhering to them, about one foot or more from the top, the small cockscomb oyster, small serpulæ, &c. consequently they must have been that distance protruded from the hard mud, but the water being thick and discoloured, the people of Battoo had not taken notice of them antecedent to the earthquake.

These tube shells differ very much among themselves, not one of them being correspondent in size or thickness to another. The large end of the shell is completely closed, and has a rounded appearance; at this part it is very thin. The small end or apex is very brittle, and is divided by a longitudinal septum running down for eight or nine inches, forming it into two distinct tubes, inclosed within the outer one, from whence the animal throws out tentacula; the substance of the shell is composed of layers having a fibrous and radiated appearance, covered externally with a pure white crust, and internally is of a yellow tinge; the external surface is frequently interrupted in a transverse direction by a sudden increase of thickness, which probably indicates different stages in the growth of the shell, although they are at unequal distances, sometimes at six inches, at others four, in the same shell. These interruptions bear a rude and unfinished appearance, and do not extend into the radiated substance, but are merely on the outside shell, which has rather a smooth surface, but at the same time impressed with the irregularities of the substance with which it was in contact. These shells all differ in thickness, some being not more than one-eighth of an inch, others full half an inch in substance; many are nearly straight, others crooked and contorted. The internal surface is in general smooth, though in some of them covered with excrescences resembling tubercles, and without any indication of the animal having adhered to any part of it.

It is the great length and size of these shells, which are the largest of the testacea of a tubular form yet discovered, and the division in the upper part, which constitute their principal peculiarities. I should add, that on their being broken in a transverse direction, the body of the shell between the inner surface and the outer crust, appears to resemble stalactites, and indeed they might easily be mistaken for them.

By consulting RUMPHIUS I found that my opinion of these tubes being entirely a new genus, was unfounded, for which, Sir, I am much indebted to your kind attention. He is th only original author, I believe, who has given any account of this production, but the figure of the shell in RUMPHIUS is somewhat different from those I have described; it exhibits two long jointed tubes, issuing from the upper part of the exterior tube; and he describes them to be found in shallow water among the mangrove trees; in the account given by RUMPHIUS there is a description both of the ground in which they are found, and the mode in which the large end of the shell is closed, exactly similar to what I have stated, so that it is evidently of the same genus, but, as it differs in having the two tubes through which the tentacula pass out, of considerable length, and entirely separate, a circumstance which may be connected with the situation of the animal in shallow water among mangroves, this, I apprehend, must be clearly admitted to be an entirely new species.

Mr. HOME, who has interested himself in the natural history of this animal, has taken the trouble to arrange the drawings for the further illustration of the subject, which have been executed under his inspection from the specimens I have brought to this country; and I shall be happy if my materials, or any I can procure from Sumatra, may enable that gentleman to make any further observations on this curious production of nature.

New Burlington Street,
January 23d, 1806.

EXPLANATION OF THE DRAWINGS. (Plate X.)

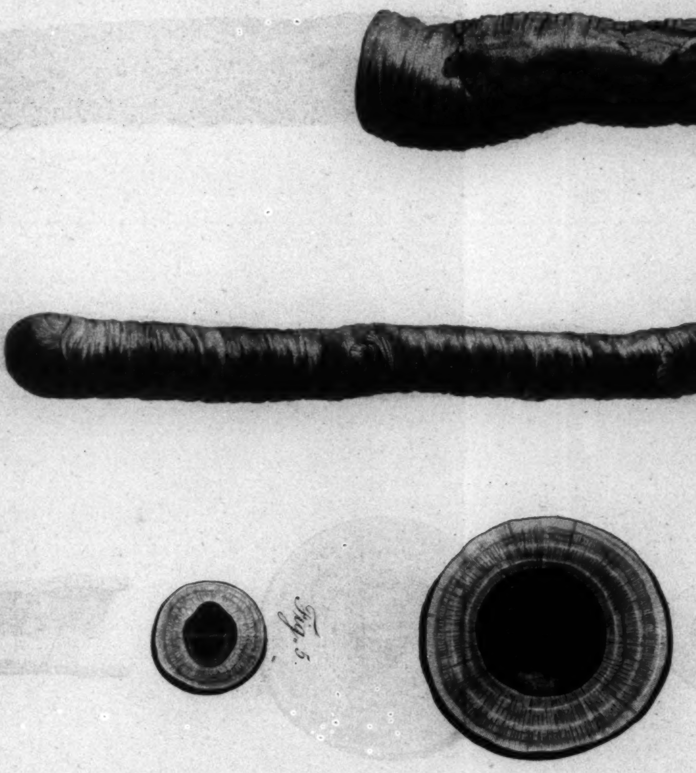
Fig. 1, Is a representation of the whole shell in the most perfect state in which its parts have been seen, and there is reason to believe that the only part wanting is the orifice of the double tube. The drawing is made upon a scale of 2½ inches to a foot.

Fig 2, A drawing of the small termination of the shell. At its lower part, for an inch in length, it exhibits the usual appearance of the external surface, but from thence to the end, it is very irregular, and in some specimens small shells of oysters, small serpulæ, &c. adhered to it. All this surface was probably above the mud, exposed to the sea water. At the upper extremity one of the tubes is broken, shewing the size of its canal, also that it is connected with the outer tube in which it is inclosed. The other tube is a little bent, and diverging outwardly, and this is probably its natural termination.

Fig. 3, Represents a section of the shell, at that part where it forms a double tube, to shew the origin of the two tubes, the thickness of the septum between them, and the two orifices leading into them.

Fig. 4, Is a transverse section of the shell at the thickest part, after it had been polished, to shew that it is made up of strata of crystals surrounding one another in concentric circles; also a front view of the orifices into the double tube.

Fig. 5. A front view of the orifices into the double tube, also shewing the thickness of the shell at that part, the canal of which has an oval form.


Scale of 3 Inches to a Foot.
Fig. 5

Wm Clift del.

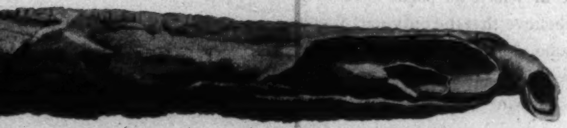


Fig. 2.

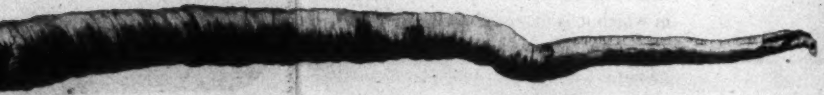


Fig. 1.

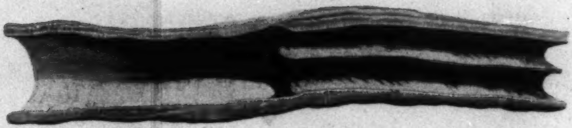


Fig. 3.

Fig. 4.

Basire sc.

Fig. 6

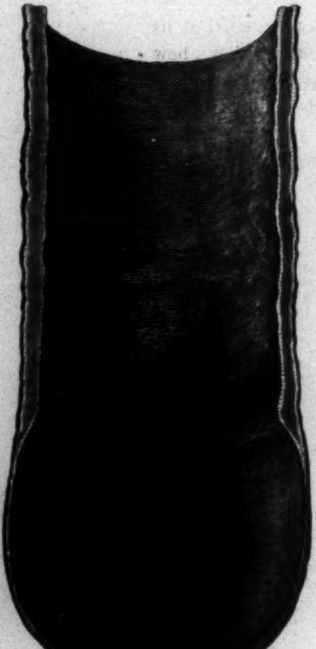
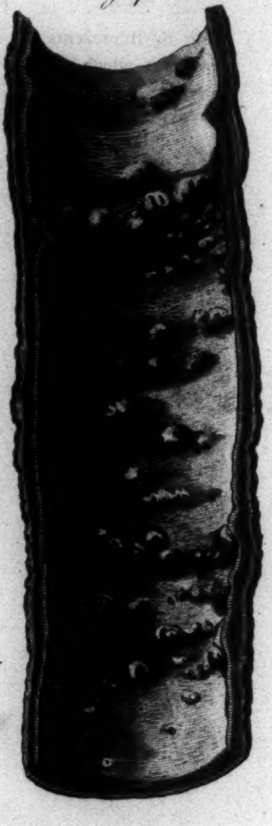


Fig. 7



ift del.

Basire sc.

Plate XI.

Fig. 6, Represents the internal cavity of the shell at its lower part, which is every where smooth; it also shews how very thin the shell is which closes up the extremity, compared with that of the general tube, which is also thinnest at the lowest part.

Fig. 7, A section of a specimen which had the tuberculated appearance on its internal surface.

XIII. *Observations on the Shell of the Sea Worm found on the Coast of Sumatra, proving it to belong to a Species of Teredo; with an Account of the Anatomy of the Teredo Navalis.* By Everard Home, *Esq. F. R. S.*

Read May 1, 1806.

The shell of the sea worm from Sumatra, had only to be seen by any one engaged in comparative anatomy, to arrest his attention, and excite a desire for further information respecting it.

In the spring 1805, Captain Maxwell of the Calcutta East Indiaman, obligingly gave me a specimen of this shell, five feet long, but imperfect at both extremities. He said it was brought from Sumatra, but could give me no further account of it. The appearance externally, and its radiated structure, led many of my friends to consider it as a mineral substance, formed into a hollow stalactite. Sir Joseph Banks, however, decided on its being the shell of a sea worm. The only means of ascertaining this point then in our power was adopted. It was analysed by Mr. Hatchett, who found that it was composed of carbonate of lime, and an animal gelatinous substance, which is greater in quantity than in the *chama gigas*, but less than in the common oyster.

Having determined that it was a shell, I applied to Mr. Marsden, as the person best acquainted with the natural history of Sumatra, for further particulars respecting it. He introduced me to his friend Mr. GRIFFITHS, who favoured Sir JOSEPH BANKS with the account, which has already been laid before this learned Society, and also put into my possession a variety of specimens of the shell, to assist me in prosecuting the subject.

There were no facts, by which the genus of the worm, to which this shell belongs, could be ascertained. Sir JOSEPH BANKS, however, had no doubt of its being a teredo. This opinion rendered the subject still more interesting, since it does not, like other teredines, live in wood. The truth of Sir JOSEPH BANKS's opinion has been since established by the discovery of the two boring shells, and the two flattened opercula, which form the decided character of teredines; these were found inclosed in one of the specimens.

The internal structure and economy of teredines are so little known, and much of what is said of them by SELLIUS, the most classical author on that subject, is so vague, that it became necessary to acquire an accurate knowledge of the common teredo navalis, before any adequate idea could be formed of this new species, which may be called Teredo Gigantea.

In this investigation the encouragement and assistance of Sir JOSEPH BANKS were not wanting. By the kindness of Mr. WHITBEY, Master Attendant at Woolwich Yard, and a Fellow of this Society, he procured pieces of wood from Sheerness, in which the animals were alive; at his solicitation the Trustees of the British Museum permitted me, with their usual liberality, to examine a specimen of a teredo preserved in spirits of a very large size: and from the HUNTERIAN collection another store was opened to me of specimens preserved in spirits.

These opportunities, the able assistance of Mr. Clift, who has been indefatigable in making the drawings, and the aid of Mr. Brodie, have enabled me to draw up the following account of the teredo navalis.

The teredines preserved in salt water lived for three days after being brought to town, which gave me an opportunity of making observations upon them. When the surface of the wood was examined in a good light, while only an inch in depth in sea water, the animal was seen to throw out sometimes one, at others two small tubes. When one only was protruded the other almost immediately followed it. One of these was about ¼ of an inch long; the other only half that size. When the largest was exposed to its full extent, there was a fringe on the inside of its external orifice, of about twenty small tentacula, scarcely visible to the naked eye: these were never seen except in that state; for when the tube was retracted, the end was first drawn in, and so on, until the whole was completely inverted: and therefore in a half protruded state it appeared to have a blunt termination, with a rounded edge. The smaller tube was not inverted when drawn in.

These tubes, while playing about in the water appeared at different times to vary in their directions, but usually remained at the greatest convenient distance from each other. The largest was always the most erect, and its orifice the most dilated: the smaller one was sometimes bent on itself with its point touching the wood.

In one instance where a small insect came across the larger one, the point of the smaller turned round, and pushed it off, and then went back to its original situation.

In several instances the smaller one appeared to be the most sensible: since by touching the larger one gently, it did not retract; but on touching the smaller one they both were instantly drawn in. Indeed whenever they were retracted, they always were drawn in together.

When the worm was confined within the shell, the orifice was not to be distinguished in the irregular surface of the wood, which was covered by small fuci.

The worm appears commonly to bore in the direction of the grain of the wood, but occasionally it bores across the grain, to avoid the track of any of the others: and in some instances there was only a semi-transparent membrane, as a partition between two of them.

In examining the shell while in the wood, its external orifice is very small, just large enough to give a passage to the two small tubes. The sides of the cylinder are thickest near its origin, becoming thinner towards the head of the animal. The greatest thickness met with was $\frac{1}{24}$ of an inch. The canal in the wood at its termination, and for one inch in length, is not lined with shell, but smeared over with a dirty green-coloured mucus, which is also spread upon the last formed portion of shell. The shell was found, when analysed by Mr. HATCHETT, to be perfectly similar to that of the teredo gigantea, being devoid of phosphate of lime, and composed of 97 parts of carbonate of lime, and 3 of animal matter.

While the animal is in the shell, alive and undisturbed, the head is in contact with the end of the canal in the wood; but on laying the head bare, it is drawn in for an inch into the shell. The body of the animal fills the area of the shell completely: but appears much smaller when taken out, in consequence of the sea water, which it contained, having escaped.

The worms that were examined were of very different lengths. The largest is represented in the annexed drawing, (Plate XII. Fig. 1,) and was 8 inches long. Many of them were alive 24 hours after being removed from their shell: and in these the heart was distinctly seen to palpitate. The blood contained in the vessels going to the head was of a red colour, as also the parts near the liver; but this colour disappeared soon after death.

The head of the worm is inclosed between the two boring shells, which are concave, so that the face, if the expression is admissible, is the only part exposed. The shells in their external form are sufficiently displayed in the drawings, to make a particular description of them unnecessary.

The shells are united together, on what may be called the back part of the head by a very strong digastric muscle, having a middle tendon, from which the fibres go off in a somewhat radiated direction, partly to be inserted into the concave surface of each shell, and partly into a long semicircular process, projecting from the posterior part of each shell. The two inclose the œsaphagus, and other parts surrounding it. The form of the process is shewn in the annexed drawing. The double muscle is inclosed in a smooth shining fascia. When first exposed it was of a bright red colour.

On the opposite side of the head the shells are united by a ligament, from which they are readily separated; at this part there are two small tooth-like processes; one from the narrow edge of each shell, where they are joined together.

From the middle of the exposed part of the head, projects a kind of proboscis: which in the living animal has a vermicular motion: its extremity is covered by a cuticle of a convex form, not unlike the cornea of the eye. When this is removed, the cavity immediately under it is found to contain a hard brown-coloured gelatinous substance, of the form of a Florence flask, with the large end upwards. As this proboscis has no orifice in it, there is reason to believe that it adheres to the wood, acting as a centre bit, while the animal is at work with the shells; and by this means the canal in the wood is so perfectly cylindrical.

The mouth of the animal is nearly concealed by the projection of the proboscis, but when exposed is a very distinct round orifice; between the proboscis and the large digastric muscle.

The body of the worm is inclosed in one general covering, extending from the base of the boring shells, with which it is firmly connected, to the root of the two small tubes, which appear out of the wood. It terminates in a small double fold, forming a cup, on the inside of which are fixed the long small stems of two opercula, which become broad and flat towards their other extremity. These, when brought together, shut up the shell, and inclose the two contracted tubes within it: not one operculum corresponding to each tube, but in a transverse direction. In the teredo gigantea, the opercula are similarly situated, each shutting up one half of the bifurcation.

At the base of this cup the general covering is thick, and ligamentous, for about ¼ of an inch in length, where the stems of the opercula are connected with it; and at one spot of this thickened part, there is an adhesion to the cylindrical shell, which is the only part of the animal connected with it. There is a depression in the shell pointing out this spot. The double fold of the outward covering, that forms the cup, contains the sphincter muscle, which closes the orifice by bringing the opercula together.

The general covering is composed of two membranes, the outer the strongest, and made up of circular fibres, the inner much finer, having no fibrous structure. On the back of the animal, this covering is firmly connected to the parts underneath, and is there strongest. On the belly it forms a cavity, and is thinner. It is every where sufficiently transparent, to shew the different viscera through it.

In examining the internal structure of this worm, the dissection was begun by dividing this covering, and exposing its cavity; into which there are two natural openings: one, that of the largest of the tubes above described, by which it receives water from the sea: the other a transverse slit under the union of the boring shells, $\frac{1}{4}$ of an inch long, opening into the space before the mouth. The smaller tube has no communication with this cavity, nor is there any between this cavity and that of the belly; the viscera having a proper covering of their own: but the breathing organs, which are attached on the posterior surface of this cavity, have their fringed edge, loose, and exposed to the influence of the salt water; so that the larger tube is constantly applying salt water to them, and conveying it to the animal's mouth, through the aperture for that purpose.

The abdominal viscera with the head occupy about one third of the animal's length: the breathing organs another, and the space between their termination and the ends of the small tubes the remaining third.

In tracing the intestinal canal from the mouth, the œsophagus is found to be very short, and lies on the left side of the neck. On the right side are two large glands near each other, connected with its coat. The œsophagus gradually swells out and becomes stomach, which to external appearance is a large bag, extending the whole length of the abdomen, and the intestine begins close to the termination of the œsophagus: but when the stomach is laid open, there is a septum dividing it into two distinct bags, except at the lower end, where they communicate. It may therefore be said to be doubled on itself. In those worms, which were examined alive, the stomachs were quite empty, but in some preserved specimens the contents were a yellow coloured pulp; and the quantity in that of the specimen from the British Museum was about 10 grains. This pulp was examined by Mr. Hatchett, who considers it to be undoubtedly, an impalpable vegetable sawdust; since when burnt the smoke had precisely the odour of wood, and it formed a charcoal easily consumed, and was converted into white ashes in every respect like vegetable charcoal. Solution of potash did not act upon it, as it would have done had it been an animal substance.

The intestine is extremely small in size; it dilates into a cavity, containing a hard white globular body, of the size of a large pin's head, and then makes a turn upon itself. At this part the liver is attached to the stomach, and adheres so firmly as to be with difficulty separated. The gut passes forwards, till it reaches the central line of the stomach, just opposite the septum, and continues its course along that viscus, passing round its lower end, and up again on the opposite side. It is then continued on one side of the œsophagus nearly as high as the mouth, where it is reflected over the middle tendon of the digastric muscle of the boring shells, and runs along the back of the animal, till it terminates in the small tube, through which it empties its contents.

The testicles are two long glandular substances, one on each side of the stomach, of a white colour, and granulated structure. From each of them a duct passes to the ovaria, which lie between the two breathing organs. The ducts run upon their outer edge, and terminate near the base of the small tube, and in this way the eggs are impregnated, before they pass out at that orifice.

In the worms examined in February, from Sheerness, the testicles were small, and no appearance of ovaria could be seen: but in some specimens from the Hunterian Museum the testicles were much fuller: and the ovaria formed two distinct longitudinal ridges; which, when examined in the microscope, contained innumerable small eggs; when the ovaria are empty, there is nothing to be found between the two breathing organs but the small seminal vessels.

Sellius mentions that the teredo navalis has its ovaria full of eggs, in the spring and summer: that they are met with as late as December, but those teredines, which he examined in February had their ovaria flaccid and empty.

The heart is situated on the back of the animal; in the middle between the mouth and the lower end of the stomach. It consists of two auricles, composed of a thin dark-coloured membrane; these open by contracted valvular orifices into two white strong tubes, which unite and form the ventricle.

The ventricle may be said to be continued into an artery, which supplies the viscera and goes up to the muscle of the two boring shells. The heart is very loosely connected to the surrounding parts; its action was very distinctly seen through the external covering, and was in some instances continued after it was laid bare. The first contraction is in the two auricles, which shorten themselves in that action. This produces a swelling of the ventricle, followed by a contraction. The artery from the ventricle can be traced up to the head, and the vessels from the auricles are seen very distinctly as far as the breathing organs. The auricles are lined by a black pigment, so that their contents cannot be seen through them, and the ventricle is too thick in its coats to be transparent: but the muscle of the boring shells is of a red colour, as well as the liver, and most of the surrounding parts, between the heart and the head.

This structure of the heart admits only of a single circulation, as in other animals which breathe through the medium of water, but the mode of its being performed is different from that in fishes; in the teredines the blood passes directly from the heart to the different parts of the body, and returns through the vessels of the breathing organs to the heart, while in fishes it goes first to the breathing organs, and then to the different parts of the body.

This peculiar circulation becomes a link in the gradation of the modes of exposing the blood to the air in different animals, it appears to be less perfect than in fishes, since the exposure to the air is carried on more slowly, but is more perfect than in caterpillars.

It is common to animals that have the same general economy whether their blood has red globules or not, and whether they breathe air or through water. In proof of this it was met with by M. Cuvier in the oyster, in the snail tribe, and all the mollusques which creep on their bellies.*

The mode, in which the breathing organs of the teredines are supplied with water, makes it evident that all sea worms, as well as other soft animals, which have no cavity for the reception of sea water, must have the breathing organs placed externally. This is the case with all those species of *Actinia* met with in the West Indies, called Animal Flowers; and the beautiful membranous expansions they display resembling the petals of flowers, are in fact the breathing organs, not tentacula for catching food, as their appearance led me to believe, when describing the new species, discovered in the year 1780, and which has a place in the Philosophical Transactions for 1785.

In animals so perfect in their organs as the teredines, and which have red blood, there can be no doubt of the existence of brain and nerves: but it is not to be wondered at that from the gelatinous texture of the animal they eluded every attempt to discover them, in the present investigation.

There was no material difference in the structure of the different varieties that were examined, although they varied from each other exceedingly in their size: except that in the large one from the British Museum, the heart was situated almost close to the origin of the breathing organs. All of them had vegetable matter in their stomachs. They must therefore all be inhabitants of wood, and belong to one species.

* Vide *Leçons d'Anatomie comparée,* Vol. IV. Lec. 27.

The teredo gigantea is imbedded in a different substance, and may have many other characteristic differences: although it appears from comparing the shells in which they are incased, that they are formed of exactly the same materials.

The teredo gigantea, when arrived at its full growth closes up the end of the shell. This the teredo navalis does also; and SELLIUS was induced to believe that the animal, by this act, formed its own tomb, since it could no longer destroy the wood, in which it was contained. We find, however, that in the teredo gigantea death is not a consequence of this seclusion from the substance, in which it is imbedded.

In some of the specimens in Mr. GRIFFITHS's possession, the shell is just covered in, and that part close to the termination is extremely thin, but in others is increased in thickness twenty fold: in others again the shell has not only become thick, but the animal has receded from its first inclosure, and has formed a second three inches up the tube, and afterwards a third two inches further on, and has made the sides thicker and thicker, to diminish the canal in proportion to the diminution of its own size.

These facts prove that the teredo gigantea, when arrived at its full growth, or whenever prevented from increasing its length, closes up the end of its shell, and lives a long time afterwards, furnished with food from the sea-water it receives like the actineæ. The teredo navalis closes up its shell in the same manner; it must, therefore, after that period, be supplied with food entirely through the medium of sea-water.

The teredines in their anatomical structure are more perfect than many of the other vermes, and have a portion of red blood. They turn round in their shell, with which the body has no attachment, and with which their covering only has a slight connection, at one particular spot, to prevent the external tubes from being disturbed. This motion of the animal is for the purpose of boring.

Their most striking peculiarities are, having three external openings instead of two: the stomach being unusually large, and the breathing organs having an uncommon conformation.

As the teredo gigantea bores in mud, on which it cannot be supposed to subsist, or even to receive any part of its nutriment from it, a question arises whether the teredo navalis (an animal of a much smaller size) receives its support from the wood it destroys, or is wholly supplied with food from the sea.

The following observations make the last opinion by much the most probable. The animal having red blood, and very perfect organs, necessarily requires a great deal of nourishment for the purposes of growth, and to supply the waste constantly going on: but if the aggregate of shell and animal substance is taken, it will be found equal in bulk, and greater in specific gravity, than the wood displaced in making the hole: hence it is obvious that the quantity of wood, it has taken into its body, is wholly insufficient for its formation and subsequent support. It must therefore have other means of subsistence. When once it is established that the worm can be supported, independantly of the wood, which is eaten, and can afterwards subsist, when the communication between it and the wood is cut off, it creates a doubt respecting the wood forming any part of its aliment, and makes it probable that

Fig. 1.

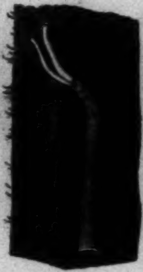


Fig. 2.

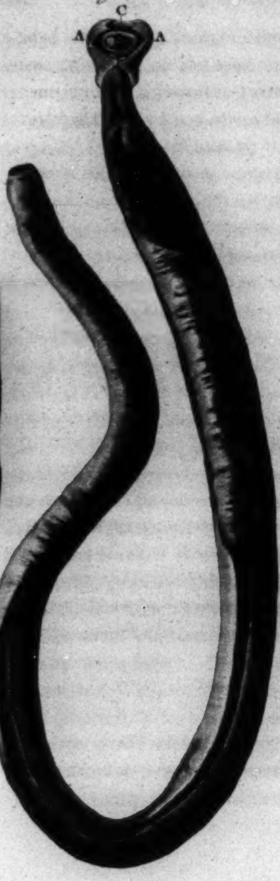


Fig. 3.

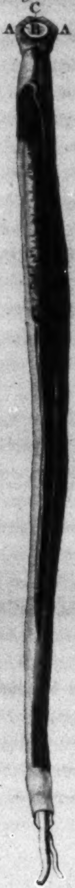


Fig. 4.

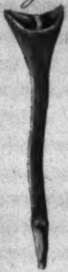


Fig. 5.

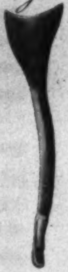
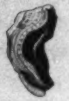


Fig. 6.



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8

9

10

W. Clift del.

Basire sc.

the teredo navalis, like the teredo gigantea, forms its habitation in a substance from which it receives no part of its sustenance: and that the sawdust conveyed through the intestines is not digested, particularly as that examined by Mr. HATCHETT, had not undergone the slightest change.

The straight course of the intestine in the teredines makes it probable that the sawdust retards the progress of the food, so as to render convolutions unnecessary. In some of the actineæ from the West Indies, the intestine is so much convoluted, that it appears to be wound round a central cylinder, in closely compacted turns.

EXPLANATION OF THE PLATES.

Plate XII.

Fig. 1, Represents a portion of the teredo navalis in its shell inclosed in the wood, to show the manner in which the two tubes are protruded, and the appearance of the shell at its termination, which is contracted but not divided into two canals as in that of the teredo gigantea.

Fig. 2, Represents the teredo belonging to the British Museum, the opercula are wanting, and the tubes are retracted.

aa, Are the boring shells.

b, The proboscis.

c, The mouth.

dd, The contents of the abdomen seen through the transparent external covering.

ee, The breathing organs seen in the same way.

Fig. 3. The teredo navalis from Sheerness, with the tubes protruded and the opercula in their situation. The letters denote the same parts as in Fig. 2. In this figure the cup containing the opercula and tubes is distinctly seen, and these parts are represented in their natural situation.

Fig. 4, Represents the external surface of one of the opercula of the teredo gigantea.

Fig. 5, Shows the other side of the same operculum.

Fig. 6, Shows a side view of the boring shell cf the same teredo with the process that projects from its concave surface, and its cutting edge.

Fig 7 and 8, Show the two sides of one of the opercula of the teredo navalis.

Fig. 9 and 10, Show two views of the boring shell of the same teredo.

All these figures are of the natural size of the parts they represent.

Plate XIII.

In this plate are three figures of the teredo from the British Museum, to show its internal structure; the different parts are represented of their natural size.

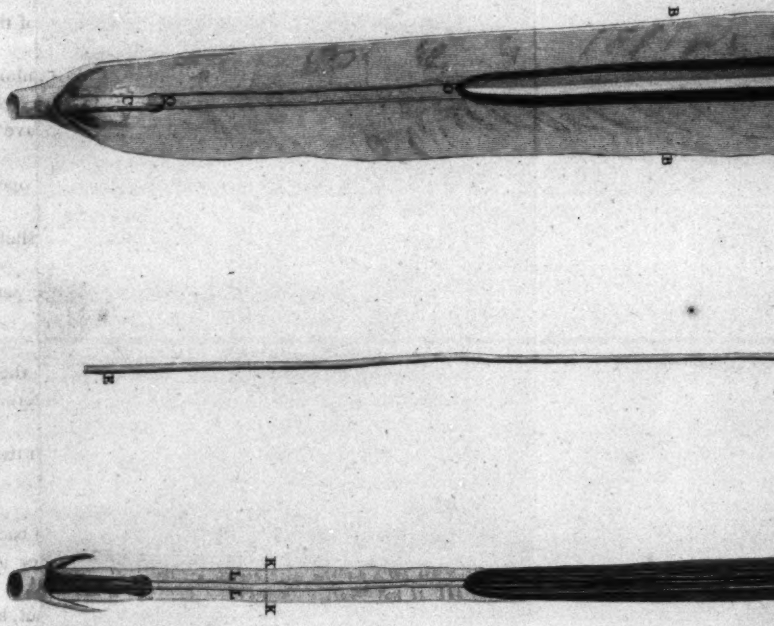
Fig. 1, Represents the animal laid open through the whole extent, exposing the abdominal view.

aa, The boring shells.

bbbb, The external covering divided and turned back.

c, The larger tube, which conveys the sea-water into that cavity, in its completely retracted state.

d, The orifice, by which the sea-water passes out, between the boring shells and the proboscis into the space before the mouth.



W^m^ Clift del.

Fig. 1.

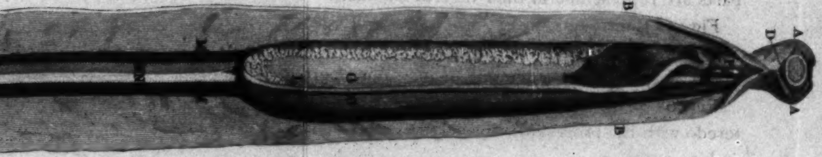


Fig. 2.

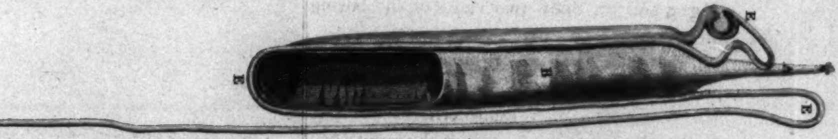
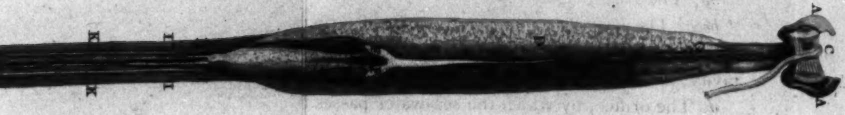


Fig. 3.



Basire sc.

e, The œsophagus.

f, Two glands which lie upon it.

gg, The stomach.

h, The liver.

ii, A portion of one of the testicles.

k, The beginning of the intestine.

ll, The intestine passing down upon the stomach.

mm, The breathing organs.

nn, The two ovaria between them.

oo, The intestine leading to its termination in the small tube behind the large one.

Fig. 2, Represents the course of the stomach and intestines removed from the body.

a, The œsophagus.

b, The stomach.

c, The septum, dividing it into two cavities.

d, The aperture by which the two cavities of the stomach communicate.

eeee, The course of the intestine to its termination.

Fig. 3, The internal structure of the animal exposed in a posterior view.

aa, The two boring shells, separated from each other and turned back.

b, The digastric muscle.

c, The intestine passing over it, and cut off to expose the other parts.

dd, The two testicles.

ee, The auricles of the heart.

ff, The ventricle of the heart.

gg, The artery going to the head.

hh, The vessels coming from the breathing organs to the heart.

ii, The breathing organs.

kkkk, The ducts of the testicles.

ll, A strong substance with transverse fibres, having a pile upon it, to strengthen this, which is the weakest part of the animal.

XIV. *On the inverted Action of the alburnous Vessels of Trees. By* Thomas Andrew Knight, *Esq. F. R. S. In a Letter to the Right Hon. Sir* Joseph Banks, *K. B. P. R. S.*

Read May 15, 1806.

MY DEAR SIR,

I HAVE endeavoured to prove, in several Memoirs[*] which you have done me the honour to lay before the Royal Society, that the fluid by which the various parts (that are annually added to trees, and herbaceous plants whose organization is similar to that of trees,) are generated, has previously circulated through their leaves[†] either in the same, or preceding season, and subsequently descended through their bark; and after having repeated every experiment that occurred to me, from which I suspected an unfavourable result, I am not in possession of a single fact which is not perfectly consistent with the theory I have advanced.

There is, however, one circumstance stated by Hales and

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[*] In the Phil. Trans. for 1801, 1803, 1804, and 1805.

[†] During the circulation of the sap through the leaves, a transparent fluid is emitted, in the night, from pores situated on their edges; and on evaporating this liquid obtained from very luxuriant plants of the vine I found a very large residuum to remain, which was similar in external appearance to carbonate of lime. It must, however, have been evidently a very different substance from the very large portion, which the water held in solution. I do not know that this substance has been analyzed, or noticed by any naturalist

DU HAMEL which appears strongly to militate against my hypothesis; and as that circumstance probably induced HALES to deny altogether the existence of circulation in plants, and DU HAMEL to speak less decisively in favour of it than he possibly might otherwise have done, I am anxious to reconcile the statements of these great naturalists, (which I acknowledge to be perfectly correct,) with the statements and opinions I have on former occasions communicated to you.

Both HALES and DU HAMEL have proved, that when two circular incisions through the bark, round the stem of a tree, are made at a small distance from each other, and when the bark between these incisions is wholly taken away, that portion of the stem which is below the incisions through the bark continues to live, and in some degree to increase in size, though much more slowly than the parts above the incisions. They have also observed that a small elevated ridge *(bourrelet)* is formed round the lower lip of the wound in the bark, which makes some slight advances to meet the bark and wood projected, in much large quantity, from the opposite, or upper lip of the wound.

I have endeavoured, in a former Memoir,* to explain the cause why some portion of growth takes place below incisions through the bark, by supposing that a small part of the true sap, descending from the leaves, escapes downwards through the porous substance of the albumnum. Several facts stated by HALES seem favourable to this supposition; and the existence of a power in the albumum to carry the sap in different directions, is proved in the growth of inverted cuttings of different species of trees.† But I have derived so many advantages, both as a gardener and farmer, (particularly in the management of fruit and forest trees,) from the experiments which have been the subject of my former memoirs, that I am confident much public benefit might be derived from an intimate acquaintance with the use and office of the various organs of plants; and thence feel anxious to adduce facts to prove that the conclusions I have drawn are not inconsistent with the facts stated by my great predecessors.

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* Phil. Trans. for 1803.

† Ibid. for 1804.

It has been acknowledged, I believe, by every naturalist who has written on the subject, (and the fact is indeed too obvious to be controverted,) that the matter which enters into the composition of the radicles of germinating seeds existed previously in their cotyledons; and as the radicles increase only in length by parts successively added to their apices, or points most distant from their cotyledons, it follows of necessity that the first motion of the true sap, at this period, is downwards. And as no alburnous tubes exist in the radicles of germinating seeds during the earlier periods of their growth, the sap in its descent must either pass through the bark, or the medulla. But the medulla does not apparently contain any vessels calculated to carry the descending sap; whilst the cortical vessels are during this period much distended and full of moisture: and as the medulla certainly does not carry any fluid in stems or branches of more than one year old, it can scarcely be suspected that it, at any period, conveys the whole current of the descending sap.

As the leaves grow, and enter on their office, cortical vessels, in every respect apparently similar to those which descended from the cotyledons, are found to descend from the bases of the leaves; and there appears no reason, with which I am acquainted, to suspect that both do not carry a similar fluid, and that the course of this fluid is, in the first instance, always towards the roots.

The ascending sap, on the contrary, rises wholly through the alburnum and central vessels; for the destruction of a portion of the bark, in a circle round the tree, does not immediately in the slightest degree check the growth of its leaves and branches: but the alburnous vessels appear, from the experiments I have related in a former Paper,* and from those I shall now proceed to relate, to be also capable of an inverted action, when that becomes necessary to preserve the existence of the plant.

As soon as the leaves of the oak were nearly full grown in the last spring, I selected in several instances two poles of the same age, and springing from the same roots in a coppice, which had been felled about six years preceding; and making two circular incisions at the distance of 3 inches from each other through the bark of one of the poles on each stool, I destroyed the bark between the incisions, and thus cut off the communication between the leaves and the lower parts of the stem and roots, through the bark. Much growth, as usual, took place above the space from which the bark had been taken off, and very little below it.

Examining the state of the experiment in the succeeding winter, I found it had not succeeded according to my hopes; for a portion of the alburnum, in almost every instance, was lifeless, and almost dry, to a considerable distance below the space from which the bark had been removed. In one instance the whole of it was, however, perfectly alive; and in this I found the specific gravity of the wood above the decorticated space to be 1114, and below it 1111; and the wood of the unmutilated pole at the same distance from the ground to be 1112, each being weighed as soon as it was detached from the root.

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* Phil. Trans. for 1804.

Had the true sap in this instance wholly stagnated above the decorticated space, the specific gravity of the wood there ought to have been, according to the result of former experiments,* comparatively much greater; but I do not wish to draw any conclusion from a single experiment; and indeed I see very considerable difficulty in obtaining any very satisfactory, or decisive facts from any experiments on plants, in this case, in which the same roots and stems collect and convey the sap during the spring and summer, and retain, within themselves, that which is, during the autumn and winter, reserved to form new organs of assimilation in the succeeding spring. In the tuberous-rooted plants, the roots and stems which collect and convey the sap in one season, and those in which it is deposited and reserved for the succeeding season, are perfectly distinct organs; and from one of these, the potatoe, I obtained more interesting and decisive results.

My principal object was to prove that a fluid descends from the leaves and stem to form the tuberous roots of this plant; and that this fluid will in part escape down the alburnous substance of the stem when the continuity of the cortical vessels is interrupted: but I had also another object in view.

Every gardener knows that early varieties of the potatoe never afford either blossoms or seeds; and I attributed this peculiarity to privation of nutriment, owing to the tubers being formed preternaturally early, and thence drawing off that portion of the true sap, which in the ordinary course of nature is employed in the formation and nutrition of blossoms and seeds.

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* Phil. Trans. for 1805.

I therefore planted, in the last spring, some cuttings of a very early variety of the potatoe, which had never been known to blossom, in garden pots, having heaped the mould as high as I could above the level of the pot, and planted the portion of the root nearly at the top of it. When the plants had grown a few inches high, they were secured to strong sticks, which had been fixed erect in the pots for that purpose, and the mould was then washed away from the base of their stems by a strong current of water. Each plant was now suspended in air, and had no communication with the soil in the pots except by its fibrous roots, and as these are perfectly distinct organs from the runners which generate and feed the tuberous roots, I could readily prevent the formation of them. Efforts were soon made by every plant to generate runners and tuberous roots; but these were destroyed as soon as they became perceptible. An increased luxuriance of growth now became visible in every plant, numerous blossoms were emitted, and every blossom afforded fruit.

Conceiving, however, that a small part only of the true sap would be expended in the production of blossoms and seeds, I was anxious to discover what use nature would make of that which remained; and I therefore took effectual means to prevent the formation of tubers on any part of the plants, except the extremities of the lateral branches, those being the points most distant from the earth, in which the tubers are naturally deposited. After an ineffective struggle of a few weeks, the plants became perfectly obedient to my wishes, and formed their tubers precisely in the places I had assigned them. Many of the joints of the plants during the experiment became enlarged and turgid; and I am much inclined to believe, that if I had totally prevented the formation of regular tubers, these joints would have acquired an organization capable of retaining life, and of affording plants in the succeeding spring.

I had another variety of the potatoe, which grew with great luxuriance, and afforded many lateral branches; and just at that period, when I had ascertained the first commencing formation of the tubers beneath the soil, I nearly detached many of these lateral branches from the principal stems, letting them remain suspended by such a portion only of alburnous and cortical fibres and vessels as were sufficient to preserve life. In this position I conceived that if their leaves and stems contained any unemployed true sap, it could not readily find its way to the tuberous roots, its passage being obstructed by the rupture of the vessels, and by gravitation; and I had soon the pleasure to see that instead of returning down the principal stem into the ground, it remained and formed small tubers at the base of the leaves of the depending branches.

The preceding facts are, I think, sufficient to prove that the fluid, from which the tuberous root of the potatoe, when growing beneath the soil, derives its component matter, exists previously either in the stems or leaves; and that it subsequently descends into the earth: and as the cortical vessels during every period of the growth of the tuber are filled with the true sap of the plant, and as these vessels extend into the runners, which carry nutriment to the tuber, and in other instances evidently convey the true sap downwards, there appears little reason to doubt that through these vessels the tuber is naturally fed.

To ascertain, therefore, whether the tubers would continue to be fed when the passage of the true sap down the cortical vessels was interrupted, I removed a portion of bark of the width of five lines, and extending round the stems of several plants of the potatoe, close to the surface of the ground, soon after that period when the tubers were first formed. The plants continued some time in health, and during that period the tubers continued to grow, deriving their nutriment, as I conclude, from the leaves by an inverted action of the alburnous vessels. The tubers, however, by no means attained their natural size, partly owing to the declining health of the plant, and partly to the stagnation of a portion of the true sap above the decorticated space.

The fluid contained in the leaf has not, however, been proved, in any of the preceding experiments, to pass downwards through the decorticated space, and to be subsequently discharged into the bark below it: but I have proved with amputated branches of different species of trees that the water which their leaves absorb, when immersed in that fluid, will be carried downwards by the alburnum, and conveyed into a portion of bark below the decorticated space; and that the insulated bark will be preserved alive and moist during several days;[*] and if the moisture absorbed by a leaf can be thus transferred, it appears extremely probable that the true sap will pass through the same channel. This power in the alburnum to carry fluids in different directions probably answers very important purposes in hot climates, where the dews are abundant and the soil very dry; for the moisture the dews afford may thus be conveyed to the extremities of the roots: and Hales has proved that the leaves absorb most when placed in humid air; and that the sap descends, either through the bark or alburnum, during the night.

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[*] This experiment does not succeed till the leaf has attained its full growth and maturity, and the alburnum of the annual shoot its perfect organization.

If the inverted action of the alburnous vessels in the decorticated space be admitted, it is not difficult to explain the cause why some degree of growth takes place below such decorticated spaces on the stems of trees; and why a small portion of bark and wood is generated on the lower lip of the wound. A considerable portion of the descending true sap certainly stagnates above the wound, and of that which escapes into the bark below it, the greater part is probably carried towards, and into, the roots; where it preserves life, and occasions some degree of growth to take place. But a small portion of that fluid will be carried upwards by capillary attraction, between the bark and the alburnum, exclusive of the immediate action of the latter substance, and the whole of this will stagnate on the lower lip of the wound; where I conceive it generates the small portion of wood and bark, which Hales and Du Hamel have described.

I should scarely have thought an account of the preceding experiments worth sending to you, but that many of the conclusions I have drawn in former memoirs appear, at first view, almost incompatible with the facts stated by Hales and

Du Hamel, and that I had one fact to communicate relative to the effects produced by the stagnation of the descending sap of resinous trees, which appeared to lead to important consequences. I have in my possession a piece of a fir-tree, from which a portion of bark, extending round its whole stem, had been taken off several years before the tree was felled; and of this portion of wood one part grew above, and the other below, the decorticated space. Conceiving that, according to the theory I am endeavouring to support, the wood above the decorticated space ought to be much heavier than that below it, owing to the stagnation of the descending sap, I ascertained the specific gravity of both kinds, taking a wedge of each as nearly of the same form, as I could obtain, and I found the difference greatly more than I had anticipated, the specific gravity of the wood above the decorticated space being 0.590, and of that below only 0.491: and having steeped pieces of each, which weighed a hundred grains, during twelve hours in water, I found the latter had absorbed 69 grains, and the former only 51.

The increased solidity of the wood above the decorticated space, in this instance, must, I conceive have arisen from the stagnation of the true sap in its descent from the leaves; and therefore in felling firs, or other resinous trees, considerable advantages may be expected from stripping off a portion of their bark all round their trunks, close to the surface of the ground, about the end of May or beginning of June, in the summer preceding the autumn in which they are to be felled. For much of the resinous matter contained in the roots of these is probably carried up by the ascending sap in the spring, and the return of a large portion of this matter to the roots would probably be prevented:* the timber I have, however, very little doubt would be much improved by standing a second year, and being then felled in the autumn; but some loss would be sustained owing to the slow growth of the trees in the second summer. The alburnum of other trees might probably be rendered more solid and durable by the same process; but the descending sap of these, being of a more fluid consistence than that of the resinous tribe, would escape through the decorticated space into the roots in much larger quantity.

It may be suspected that the increased solidity of the wood in the fir-tree I have described was confined to the part adjacent to the decorticated space; but it has been long known to gardeners, that taking off a portion of bark round the branch of a fruit-tree occasions the production of much blossom on every part of that branch in the succeeding season. The blossom in this case probably owes its existence to a stagnation of the true sap extending to the extremities of the branch above the decorticated space; and it may therefore be expected that the alburnous matter of the trunk and branches of a resinous tree will be rendered more solid by a similar operation.

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* The roots of trees, though of much less diameter than their trunks and branches, probably contain much more alburnum and bark, because they are wholly without heart wood, and extend to a much greater length than the branches; and thence it may be suspected that when fir-trees are felled, their roots contain at least as much resinous matter, in a fluid moveable state, as their trunks and branches; though not so much as is contained, in a concrete state, in the heart wood of those.

I send you two specimens of the fir wood I have described, the one having been taken off above, and the other below, the decorticated space. The bark of the latter kind scarcely exceeded one-tenth of a line in thickness; the cause of which I propose to endeavour to explain in a future communication relative to the reproduction of bark.

I am, &c.

T. A. KNIGHT.

XV. *A new Demonstration of the Binomial Theorem, when the Exponent is a positive or negative Fraction. By the Rev.* Abram Robertson, *A. M. F. R. S. Savilian Professor of Geometry in the University of Oxford. In a Letter to* Davies Giddy, *Esq. F. R. S.*

Read June 5, 1806.

DEAR SIR,

BEING perfectly convinced of your love of mathematical science, and your extensive acquirements in it, I submit to your perusal a new demonstration of the binomial theorem, when the exponent is a positive or negative fraction. As I am a strenuous advocate for smoothing the way to the acquisition of useful knowledge, I deem the following articles of some importance; and unless I were equally sincere in this persuasion, and in that of your desire to promote mathematical studies, in requesting the perusal, I should accuse myself of an attempt to trifle with your valuable time.

The following demonstration is new only to the extent above mentioned; but in order that the reader may perceive the proof to be complete, a successive perusal of all the articles is necessary. As far as it relates to the raising of integral powers, it is in substance the same with one which I drew up in the year 1794, and which was honoured with a place in the Philosophical Transactions for 1795. If, therefore, you think the following demonstration worthy the attention of mathematicians, you will much oblige me by presenting it to the Royal Society.

I am, &c.

A. ROBERTSON.

Oxford,
March 21st, 1806.

1. The binomial theorem is a general expression for any power of the sum or difference of two quantities. Thus if n be any positive or negative whole number, or vulgar fraction, and a, b, be any two quantities, the binomial theorem expresses in a series the value of $\overline{a+b}|^{n}$, or $\overline{a-b}|^{n}$.

The binomial theorem is of very extensive utility. Besides the advantages derived from it in raising powers and extracting roots, it enables us to conduct, with clearness and ease, a variety of investigations in the higher parts of algebra, which, without its assistance, would become perplexed and laborious.

2. If n be a whole positive number, we can raise $x+a$ to the power denoted by n, in the following manner, by multiplication.

$$
\begin{array}{l}
x+a \\
x+a \\
\hline
x^2+ax \\
\qquad ax+a^2 \\
\hline
x^2+2ax+a^2=\overline{x+a}|^2 \\
x+a \\
\hline
x^3+2ax^2+a^2x \\
\qquad ax^2+2a^2x+a^3 \\
\hline
x^3+3ax^2+3a^2x+a^3=\overline{x+a}|^3 \\
x+a \\
\hline
x^4+3ax^3+3a^2x^2+a^3x \\
\qquad ax^3+3a^2x^2+3a^3x+a^4 \\
\hline
x^4+4ax^3+6a^2x^2+4a^3x+a^4=\overline{x+a}|^4, \\
\qquad\qquad \text{\&c.}
\end{array}
$$

In the same manner the value of $\overline{x-a}|^n$ may be obtained; and its only difference from the value of $\overline{x+a}|^n$ will consist in having the negative sign prefixed to such terms as have an odd power of a. And as the powers of any other quantity, either simple or compound, may be obtained gradually by multiplying the last found power by the root, in order to find the next higher power, it is manifest that the principles of multiplication are the most simple and evident, to which we can resort, for the demonstration of the binomial theorem. These principles, therefore, will be used throughout the whole of the following investigations on the subject, and by them every case of the theorem will be established.

It is well known to mathematicians that the theorem has been repeatedly proved, either by induction, by the summation of figurate numbers, by the doctrine of combinations, by assumed series, or by fluxions; but that multiplication is a more direct way to the establishment of the theorem than any of these, cannot, I think, be doubted. Proceeding by multiplication, we have always an evident first principle in view, to which without the aid of any doctrine, foreign to the subject, we can appeal for the truth of our assertions, and the certainty and extent of our conclusions.

3. If p, q, be any two quantities, the product arising from the multiplication of p by q is equal to the product arising from the multiplication of q by p.* For magnitudes being to one another as their equimultiples, $p \times q : 1 \times q :: p : 1$, and $q \times p : 1 \times p :: q : 1$. But $1 \times q = q$, and $1 \times p = p$, and therefore, placing for ex æquali in a cross order,

$$\begin{array}{l} p \times q : q : 1 \\ q \times p : p : 1. \end{array}$$

Consequently, $p \times q : 1 :: q \times p : 1$, and therefore $pq = qp$.

Hence it follows that the product arising from the multiplication of any number of quantities into one another, continues the same in value, in every variation which may be made in the arrangement of the quantities which compose it. Thus p, q, r, s, being any quantities, $pqrs = pqr \times s = spqr = spq \times r = rspq = rsp \times q = qrsp = qr \times s \times p = qr \times p \times s = qrps$, &c. And if $x + a = p$, $x + b = q$, $x + c = r$, $x + d = s$, $x + e = t$, &c. then $\overline{x+a} \times \overline{x+b} \times \overline{x+c} \times \overline{x+d} \times \overline{x+e} = pqrst = \overline{x+a} \times \overline{x+b} \times$

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* When I speak of the multiplication of quantities into one another, I mean the multiplication of the numbers into one another which measure those quantities.

$\overline{x+c}\times\overline{x+e}\times\overline{x+d}=pqrts=$ any other arrangement which can take place in the quantities.

4. It is evident that each of the quantities a, b, c, &c. will be found the same number of times in the compound product arising from $\overline{x+a}\times\overline{x+b}\times\overline{x+c}\times\overline{x+d}\times\overline{x+e}$, &c. For this product is equal to $pqrst=pqrs\times\overline{x+e}=pqrt\times\overline{x+d}=pqst\times\overline{x+c}=prst\times\overline{x+b}=qrst\times\overline{x+a}$, by substituting for the compound quantities, $x+a$, $x+b$, &c. their equals p, q, &c. Wherefore, in the compound product, each of the quantities a, b, c, &c. will be found multiplied into the products of all the others.

5. These things being premised, we may poceed to the multiplication of the compound quantities $x+a$, $x+b$, $x+c$, &c. into one another; and in order to be as clear as possible in what follows, let us consider the sum of the quantities, a, b, c, &c. or the sum of any number of them multiplied into one another, as coefficients to the several powers of x, which arise in the multiplication. By considering products which contain the same number of the quantities a, b, c, &c. as homologous, the multiplication will appear as follows, and equations of various dimensions will arise, according to the powers of x.

$$\begin{array}{l} x+a=p \\ \underline{x+b=q} \end{array}$$

$$\left.\begin{array}{l} x^2+a \\ \quad\; +b \end{array}\right\} x+ab=pq;$$ a quadratic equation, or an equation of two dimensions.

$$\underline{x+c=r}$$

$$\left.\begin{array}{l} x^3+a \\ \quad\; +b \\ \quad\; +c \end{array}\right\} x^2 \left.\begin{array}{l} +ab \\ +ac \\ +bc \end{array}\right\} x+abc=pqr;$$ a cubic, or an equation of three dimensions.

$$\underline{x+d=s}$$

$$\left.\begin{array}{l} x^4+a \\ \quad\; +b \\ \quad\; +c \\ \quad\; +d \end{array}\right\} x^3 \left.\begin{array}{l} +ab \\ +ac \\ +bc \\ +ad \\ +bd \\ +cd \end{array}\right\} x^2 \left.\begin{array}{l} +abc \\ +abd \\ +acd \\ +bcd \end{array}\right\} x+abcd=pqrs;$$ a biquadratic, or an equation of four dimensions.

$$\underline{x+e=t}$$

$$\left.\begin{array}{l} x^5+a \\ \quad\; +b \\ \quad\; +c \\ \quad\; +d \\ \quad\; +e \end{array}\right\} x^4 \left.\begin{array}{l} +ab \\ +ac \\ +bc \\ +ad \\ +bd \\ +cd \\ +ae \\ +be \\ +ce \\ +de \end{array}\right\} x^3 \left.\begin{array}{l} +abc \\ +abd \\ +acd \\ +bcd \\ +abe \\ +ace \\ +bce \\ +ade \\ +bde \\ +cde \end{array}\right\} x^2 \left.\begin{array}{l} +abcd \\ +abce \\ +abde \\ +acde \\ +bcde \end{array}\right\} x+abcde=pqrst;$$ a surſolid, or an equation of five dimensions.

&c.

6. From the above it appears, that the coefficient of the highest power of x in any equation is 1; but the coefficient of any other power of x in the same equation consists of a certain number of members, each of which contains one, two, three, &c. of the quantities a, b, c, &c. Thus the coefficient of

the second term of any equation is made up of members, each of which contains only one of the quantities a, b, c, &c. and the whole coefficient of the second term is the sum of all these members, or the sum of all the quantities a, b, c, &c. used in the multiplication by which the equation, under consideration, was produced. Thus in the equation of four dimensions, the whole coefficient of the second term is $a+b+c+d$, and a, b, c, d, were used in the multiplication in obtaining the equation. The coefficient of the third term, of any equation, is made up of members, each of which contains two of the quantities a, b, c, &c. used in the multiplication in obtaining the equation. Thus in the equation of four dimensions, the whole coefficient of the third term is $ab+ac+bc+ad+bd+cd$. And indeed, not only from inspection, but also from considering the manner in which the equations are generated, it is evident that each member of any coefficient has as many of the quantities a, b, c, &c. in it, as there are terms in the equation preceding the term to which the coefficient belongs. Thus each member of the coefficient in the second term of any equation is one quantity only, and only one term precedes the second term. Each member of the coefficient in the third term, of any equation, consists of two quantities, and two terms precede the third, &c.

7. When any equation is multiplied in order to produce the equation next above it, it is evident that the multiplication by x produces a part in the equation to be obtained, which has the same coefficients as the equation multiplied. Thus, multiplying the equation of three dimensions by x we obtain that part of the equation of four dimensions which has the same

coefficients as the cubic: the only effect of this multiplication being the increase of the exponents of x by 1.

8. But when the same equation is multiplied by the quantity adjoined to x by the sign $+$, each term of the product, in order to rank under the same power of x, must be drawn one term back. Thus when the first term of the cubic is multiplied by d, the product must be placed in the second term of the biquadratic. When the second term of the cubic is multiplied by d, the product must be placed in the third term of the biquadratic: and so of others.

9. As the equation last produced is the product of all the compound quantities $x+a$, $x+b$, $x+c$, &c. into one another, and as it was proved in the fourth article that each of the quantities a, b, c, &c. must be found the same number of times in this product, if we can compute the number of times any one of those quantities enters into the coefficient of any term of the last equation, we shall then know how often each of the other enters into the same coefficient: and this may be done with ease, if of the quantities a, b, c, &c. we fix upon that used in the last multiplication. For the last equation, and indeed any other, may be considered as made up of two parts; the first part being the equation immediately before the last multiplied by x, according to the 7th article, and the second part being the same equation multiplied by the quantity adjoined to x by the sign $+$, last used in the multiplication, according to the 8th article. This last used quantity, therefore, never enters into the members of the coefficient of the first of these two parts, but it enters into all the members of the coefficients of the last of them. But that part into which it

does not enter has the same members as the coefficients of the equation immediately before the last, by the 7th article; and when the members of the first part are multiplied by the last used quantity, the product becomes the second part of the whole coefficient above mentioned.

Thus the first part of the cubic equation, by the 7th article is, $x^3 \left.\begin{matrix}+a\\+b\end{matrix}\right\} x^2 + abx$, and as these coefficients are the same as the coefficients in the quadratic equation, being multiplied by c, and arranged according to the 8th article, we have the coefficients of the second part of the cubic, viz. $c \begin{matrix}+ac\\+bc\end{matrix} + abc$.

Hence it is evident, that there are as many members in any coefficient, which have the last used quantity in them, as there are members in the coefficient preceding, which have not the same quantity. Thus in the 3d term, in the equation of four dimensions, there are three members of the whole coefficient of x^2 which have d in them, viz. ad, bd, cd, and there are three members of the whole coefficient of x^3 in the second term, which have not d in them, viz. a, b, c. In the fourth term of the same equation, there are three members of the whole coefficient of x, which have d in them, viz. abd, acd, bcd, and there are three members of the whole coefficient of x^2 in the third term which have not d in them, viz. ab, ac, bc. Now as it has been proved that each of the quantities a, b, c, &c. enters the same number of times into the coefficient of the same term, what has here been proved of the last used is applicable to each.

10. From the last article the number of members in the several coefficients of any equation may be determined. For

if we put $s=$ the number of times each quantity is found in a coefficient, $n=$ the number of quantities a, b, c, &c. used in producing the equation, and $p=$ the number of quantities in each member; then as a is found s times in this coefficient, b is found s times in this coefficient, &c. the number of quantities in this coefficient, with their repetitions, will be $s\times n$; and as p expresses the number of quantities requisite for each member, the number of members in the coefficient will be $\frac{sn}{p}$.

Thus, for the sake of illustration, if we limit the above notation to the second term of the equation of five dimensions, $s=1$, as each of the quantities a, b, c, &c. is found once in the whole coefficient of x^4; $p=1$, as each member consists of one quantity, and $n=5$, as a, b, c, d, e are used in producing the equation. Consequently $\frac{sn}{p}=5$. If we limit the above notation to the third term of the same equation, $s=4$, $p=2$, and $n=5$, and therefore $\frac{sn}{p}=10$. If we limit the above notation to the fourth term of the same equation, $s=6$, $p=3$, and $n=5$, and $\frac{sn}{p}=10$. If we limit the above notation to the fifth term of the same equation, $s=4$, $p=4$, and $n=5$, and $\frac{sn}{p}=5$.

11. Using the same notation, we can by the last two articles, calculate the number of members in the next coefficient after that whose number of members is $\frac{sn}{p}$. For as $\frac{sn}{p}$ expresses the number of members in the above mentioned coefficient, and s the number of times each quantity is found in it, $\frac{sn}{p}-s=$ the number of times each is not found in it. By the 9th article therefore, a will be found $\frac{sn}{p}-s$ times, b will be found $\frac{sn}{p}-s$ times, &c. in the next coefficient, and therefore $\overline{\frac{sn}{p}-s}\times n=\frac{sn^2-psn}{p}=$ the number of quantities, with

their repetitions, in it. But as the number of quantities in each member of a coefficient is 1 less than the number in each member of the coefficient next following, each member of the coefficient whose number of members we are now calculating will have in it $p+1$ number of quantities. Consequently $\frac{sn^2-psn}{p\times\overline{p+1}}=\frac{sn}{p}\times\frac{n-p}{p+1}=$ the number of members of the coefficient next after that whose number of members is $\frac{sn}{p}$, as in the last article.

12. It is evident, from the sixth article, that the value of p in the second term of any equation is 1; in the third term of any equation its value is 2; in the fourth term of any equation it is 3, &c. It is also evident that the number of members of the coefficient of the second term of any equation is n; for the whole coefficient is the sum of all the quantities $a, b, c,$ &c. used in producing the equation. It therefore follows that the general expression $\frac{sn}{p}\times\frac{n-p}{p+1}$, obtained in the last article, enables us to ascertain the number of members in the coefficient of any term in an equation. For the number of members of the coefficient in the second term being n, according to the successive values of p the number of members in the third term is $n.\frac{n-1}{2}$; in the fourth term it is $n.\frac{n-1}{2}.\frac{n-2}{3}$; in the fifth term it is $n.\frac{n-1}{2}.\frac{n-2}{3}.\frac{n-3}{4}$; and this regular form may be extended to express the number of members in the coefficient of any term whatever.

13. The binomial theorem, as far as it relates to the raising of integral powers, easily follows from the foregoing articles. For if all the quantities $a, b, c,$ &c. used in the multiplication in the fifth article, be equal to one another, and consequently

each equal to a, each of the members in any coefficient will become a power of a; and, therefore, as the exponent of x in the first term is equal to n, it follows from the sixth and last articles that $\overline{x+a}|^{n}=x^{n}+nax^{n-1}+n.\frac{n-1}{2}a^{2}x^{n-2}+n.\frac{n-1}{2}.\frac{n-2}{3}.a^{3}x^{n-3}+n.\frac{n-1}{2}.\frac{n-2}{3}.\frac{n-3}{4}a^{4}x^{n-4}+$ &c.

14. If equations be generated from $\overline{x-a}.\overline{x-b}.\overline{x-c}.\overline{x-d}$, &c. the coefficients will be the same, excepting the signs, as those which result from $\overline{x+a}.\overline{x+b}.\overline{x+c}.\overline{x+d}$, &c. in the fifth article; and as minus multiplied into minus gives plus, but minus multiplied into minus multiplied into minus gives minus, the coefficients in equations generated from $\overline{x-a}.\overline{x-b}.\overline{x-c}.\overline{x-d}$, &c. whose members have each an even number of the quantities a, b, c, &c. will have the sign $+$, but coefficients whose members have each an odd number of the quantities a, b, c, &c. will have the sign $-$. And hence it is evident that $\overline{x-a}|^{n}=x^{n}-nax^{n-1}+n.\frac{n-1}{2}a^{2}x^{n-2}-n.\frac{n-1}{2}.\frac{n-2}{3}a^{3}x^{n-3}+n.\frac{n-1}{2}.\frac{n-2}{3}.\frac{n-3}{4}a^{4}x^{n-4}-$ &c.

15. By the general principles of involution $\overline{a+b}|^{n}=a^{n}\times\overline{1+\frac{b}{a}}|^{n}=a^{n}\times\overline{1+x}|^{n}$, by putting $x=\frac{b}{a}$. By article 13, $\overline{1+x}|^{n}=1+nx+n.\frac{n-1}{2}x^{2}+n.\frac{n-1}{2}.\frac{n-2}{3}x^{3}+n.\frac{n-1}{2}.\frac{n-2}{3}.\frac{n-3}{4}x^{4}+$ &c. and by the same article $\overline{1+x}|^{m}=1+mx+m.\frac{m-1}{2}x^{2}+m.\frac{m-1}{2}.\frac{m-2}{3}x^{3}+m.\frac{m-1}{2}.\frac{m-2}{3}.\frac{m-3}{4}x^{4}+$ &c. But by the general principles of involution, and article 13, $\overline{1+x}|^{n}\times\overline{1+x}|^{m}=\overline{1+x}|^{n+m}=1+\overline{n+m}\,x+\overline{n+m}.\frac{n+m-1}{2}x^{2}+\overline{n+m}.\frac{n+m-1}{2}.\frac{n+m-2}{3}x^{3}+\overline{n+m}.\frac{n+m-1}{2}.\frac{n+m-2}{3}.\frac{n+m-3}{4}x^{4}+$ &c. when n and m are whole numbers.

Hence it is evident that if the series equal to $\overline{1+x}|^{n}$ be multiplied by the series equal to $\overline{1+x}|^{m}$, the product must be equal to the series which is equal to $\overline{1+x}|^{n+m}$. Now the two first mentioned series being multiplied into one another, and the parts being arranged according to the powers of x, the several products will stand as in the following representation.

$$\begin{array}{lllllll}
\overline{1+x}|^{n} = & 1 & +nx & +n.\frac{n-1}{2}x^2 & +n.\frac{n-1}{2}.\frac{n-2}{3}x^3 & +n.\frac{n-1}{2}.\frac{n-2}{3}.\frac{n-3}{4}x^4 & +\ \&c. \\
\overline{1+x}|^{m} = & 1 & +mx & +m.\frac{m-1}{2}x^2 & +m.\frac{m-1}{2}.\frac{m-2}{3}x^3 & +m.\frac{m-1}{2}.\frac{m-2}{3}.\frac{m-3}{4}x^4 & +\ \&c. \\
\hline
 & 1 & +nx & +n.\frac{n-1}{2}x^2 & +n.\frac{n-1}{2}.\frac{n-2}{3}x^3 & +n.\frac{n-1}{2}.\frac{n-2}{3}.\frac{n-3}{4}x^4 & +\ \&c. \\
 & & mx & +m.nx^2 & +m.n.\frac{n-1}{2}x^3 & +m.n.\frac{n-1}{2}.\frac{n-2}{3}x^4 & +\ \&c. \\
 & & & m.\frac{m-1}{2}x^2 & +m.\frac{m-1}{2}.nx^3 & +m.\frac{m-1}{2}.n.\frac{n-1}{2}x^4 & +\ \&c. \\
 & & & & m.\frac{m-1}{2}.\frac{m-2}{3}x^3 & +m.\frac{m-1}{2}.\frac{m-2}{3}.nx^4 & +\ \&c.
\end{array}$$

For the sake of reference hereafter let this be called multiplication A.

Now with respect to the coefficients prefixed to the several powers of x, in the foregoing multiplication, two observations are to be made, by means of which the demonstration of the theorem may be extended to fractional exponents.

In the first place, supposing n and m to be whole numbers, the sum of the coefficients prefixed to any individual power of x, in multiplication A, must be equal to the coefficient prefixed to the same power of x in the binomial series $1+\overline{n+m}x + \overline{n+m}.\frac{n+m-1}{2}x^2 + \overline{n+m}.\frac{n+m-1}{2}.\frac{n+m-2}{3}x^3 + \overline{n+m}.\frac{n+m-1}{2}.\frac{n+m-2}{3}.\frac{n+m-3}{4}x^4 + \&c.$ The certainty of this circumstance rests partly on the 13th article, and partly on a plain axiom, *viz.* that equals being multiplied by equals the products are equal.

In the second place it is to be observed, that the whole coefficient of any power of x, in the products of multiplication A, may be reduced to the regular binomial form, established in the 13th article. Thus $n \cdot \frac{n-1}{2} + mn + m \cdot \frac{m-1}{2}$, the whole coefficient of x^2, by actual multiplication becomes $\frac{n^2+m^2+2mn-n-m}{2} = \overline{n+m} \cdot \frac{n+m-1}{2}$. Also $n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} + mn \cdot \frac{n-1}{2} + m \cdot \frac{m-1}{2} \cdot n + m \cdot \frac{m-1}{2} \cdot \frac{m-2}{3}$, the whole coefficient of x^3, by actual multiplication becomes $\frac{n^3+m^3-3n^2-3m^2+3n^2m}{6} + \frac{3m^2n-6mn+2n+2m}{6} = \overline{n+m} \cdot \frac{n+m-1}{2} \cdot \frac{n+m-2}{3}$. And from the preceding observation it is evident, that we may in the same manner, reduce the whole coefficient of any other power of x, in the products of multiplication A to the regular binomial form.

16. But in proceeding, as above, to change the form of the coefficients prefixed to any power of x, in multiplication A, into the regular binomial form, we are not under the necessity of supposing n and m to be whole numbers. The actual multiplications will end in the same powers of n and m, the same combinations of them, and the same numerals, whether we consider n and m as whole numbers or as fractions.

We are therefore at liberty to suppose n and m to be any two fractions whatever, in the two series multiplied into one another in multiplication A, and the same two fractions will take the place of n and m respectively in the regular binomial series $1 + \overline{n+m}\,x + \overline{n+m} \cdot \frac{n+m-1}{2} x^2 + \overline{n+m} \cdot \frac{n+m-1}{2} \cdot \frac{n+m-2}{3} x^3$

$+\overline{n+m}.\frac{n+m-1}{2}.\frac{n+m-2}{3}.\frac{n+m-3}{4}x^4+$ &c. which expresses the product of the two series into one another.

17. If therefore r be any positive whole number we can raise the binomial series $1+\frac{1}{r}x+\frac{1}{r}.\frac{\frac{1}{r}-1}{2}x^2+\frac{1}{r}.\frac{\frac{1}{r}-1}{2}.\frac{\frac{1}{r}-2}{3}x^3+\frac{1}{r}.\frac{\frac{1}{r}-1}{2}.\frac{\frac{1}{r}-2}{3}.\frac{\frac{1}{r}-3}{4}x^4+$ &c. to any proposed power by successive multiplications; or we can express any power of it by supposing the multiplications actually to have been gone through. Thus, calling the last mentioned series the root, if it be multiplied by itself, and if the coefficients in the product be expressed in the regular binomial form, its square will be $1+\frac{2}{r}x+\frac{2}{r}.\frac{\frac{2}{r}-1}{2}x^2+\frac{2}{r}.\frac{\frac{2}{r}-1}{2}.\frac{\frac{2}{r}-2}{3}x^3+\frac{2}{r}.\frac{\frac{2}{r}-1}{2}.\frac{\frac{2}{r}-2}{3}.\frac{\frac{2}{r}-3}{4}x^4+$ &c. Again, if this series be multiplied by the root, and the coefficients in the product be expressed in the regular binomial form, the cube of the root will be $1+\frac{3}{r}x+\frac{3}{r}.\frac{\frac{3}{r}-1}{2}x^2+\frac{3}{r}.\frac{\frac{3}{r}-1}{2}.\frac{\frac{3}{r}-2}{3}x^3+\frac{3}{r}.\frac{\frac{3}{r}-1}{2}.\frac{\frac{3}{r}-2}{3}.\frac{\frac{3}{r}-3}{4}x^4+$ &c. Proceeding thus, by multiplying the last found power by the root, in order to find the next higher power, the nth power of $1+\frac{1}{r}x+\frac{1}{r}.\frac{\frac{1}{r}-1}{2}x^2+\frac{1}{r}.\frac{\frac{1}{r}-1}{2}.\frac{\frac{1}{r}-2}{3}x^3+\frac{1}{r}.\frac{\frac{1}{r}-1}{2}.\frac{\frac{1}{r}-2}{3}.\frac{\frac{1}{r}-3}{4}x^4+$ &c. is $1+\frac{n}{r}x+\frac{n}{r}.\frac{\frac{n}{r}-1}{2}x^2+\frac{n}{r}.\frac{\frac{n}{r}-1}{2}.\frac{\frac{n}{r}-2}{3}x^3+\frac{n}{r}.\frac{\frac{n}{r}-1}{2}.\frac{\frac{n}{r}-2}{3}.\frac{\frac{n}{r}-3}{4}x^4+$ &c.

18. If in the series, which concludes the last article, n be equal to r, the whole series becomes equal to $1+x$. For in this case $\frac{n}{r}=1$, and therefore $\frac{\frac{n}{r}-1}{2}=0$, and consequently every term in the series, after the second, becomes equal to 0, or vanishes.

Hence it is evident that the rth root of $1+x$, or, which is the same thing, that $\overline{1+x}|^{\frac{1}{r}}=1+\frac{1}{r}x+\frac{1}{r}\cdot\frac{\frac{1}{r}-1}{2}x^2+\frac{1}{r}\cdot\frac{\frac{1}{r}-1}{2}\cdot\frac{\frac{1}{r}-2}{3}x^3+\frac{1}{r}\cdot\frac{\frac{1}{r}-1}{2}\cdot\frac{\frac{1}{r}-2}{3}\cdot\frac{\frac{1}{r}-3}{4}x^4+$ &c. for this series being raised to the rth power becomes equal to $1+x$.

As by the general principles of involution the nth power of $\overline{1+x}|^{\frac{1}{r}}$ is $\overline{1+x}|^{\frac{n}{r}}$, it therefore follows, from the last observation and the preceding article, that $\overline{1+x}|^{\frac{n}{r}}=1+\frac{n}{r}x+\frac{n}{r}\cdot\frac{\frac{n}{r}-1}{2}x^2+\frac{n}{r}\cdot\frac{\frac{n}{r}-1}{2}\cdot\frac{\frac{n}{r}-2}{3}x^3+\frac{n}{r}\cdot\frac{\frac{n}{r}-1}{2}\cdot\frac{\frac{n}{r}-2}{3}\cdot\frac{\frac{n}{r}-3}{4}x^4+$ &c.

19. By the general principles of involution $\overline{a-b}|^n=a^n\times\overline{1-\frac{b}{a}}|^n=a^n\times\overline{1-x}|^n$, by putting $x=\frac{b}{a}$. By article 14, n being a whole number, $\overline{1-x}|^n=1-nx+n\cdot\frac{n-1}{2}x^2-n\cdot\frac{n-1}{2}\cdot\frac{n-2}{3}x^3+n\cdot\frac{n-1}{2}\cdot\frac{n-2}{3}\cdot\frac{n-3}{4}x^4-$ &c. and by the same article, m being a whole number, $\overline{1-x}|^m=1-mx+m\cdot\frac{m-1}{2}x^2-m\cdot\frac{m-1}{2}\cdot\frac{m-2}{3}x^3+m\cdot\frac{m-1}{2}\cdot\frac{m-2}{3}\cdot\frac{m-3}{4}x^4-$ &c. But by the general principles of involution, and article 14, $\overline{1-x}|^n\times\overline{1-x}|^m=\overline{1-x}|^{n+m}$

$$=1-\overline{n+m}x+\overline{n+m}\,.\,\frac{n+m-1}{2}x^2-\overline{n+m}\,.\,\frac{n+m-1}{2}\,.\,\frac{n+m-2}{3}x^3$$
$$+\overline{n+m}\,.\,\frac{n+m-1}{2}\,.\,\frac{n+m-2}{3}\,.\,\frac{n+m-3}{4}x^4-\&c.$$

Hence it is evident that if the series equal to $\overline{1-x}|^{n}$ be multiplied by the series equal to $\overline{1-x}|^{m}$, the product must be equal to the series, which is equal to $\overline{1-x}|^{n+m}$. Now the two first mentioned series being multiplied into one another, and the parts being arranged according to the powers of x, the several products will stand as in the following representation.

$$\overline{1-x}|^{n}=1-nx+n\,.\,\frac{n-1}{2}x^2-n\,.\,\frac{n-1}{2}\,.\,\frac{n-2}{3}x^3+n\,.\,\frac{n-1}{2}\,.\,\frac{n-2}{3}\,.\,\frac{n-3}{4}x^4-\ \&c.$$
$$\overline{1-x}|^{m}=1-mx+m\,.\,\frac{m-1}{2}x^2-m\,.\,\frac{m-1}{2}\,.\,\frac{m-2}{3}x^3+m\,.\,\frac{m-1}{2}\,.\,\frac{m-2}{3}\,.\,\frac{m-3}{4}x^4-\ \&c.$$

$$1-nx+n\,.\,\frac{n-1}{2}x^2-n\,.\,\frac{n-1}{2}\,.\,\frac{n-2}{3}x^3+n\,.\,\frac{n-1}{2}\,.\,\frac{n-2}{3}\,.\,\frac{n-3}{4}x^4-\ \&c.$$
$$-mx+m\,.\,nx^2-m\,.\,n\,.\,\frac{n-1}{2}x^3+m\,.\,n\,.\,\frac{n-1}{2}\,.\,\frac{n-2}{3}x^4-\ \&c.$$
$$m\,.\,\frac{m-1}{2}x^2-m\,.\,\frac{m-1}{2}\,.\,nx^3+m\,.\,\frac{m-1}{2}\,.\,n\,.\,\frac{n-1}{2}x^4-\ \&c.$$
$$-m\,.\,\frac{m-1}{2}\,.\,\frac{m-2}{3}x^3+m\,.\,\frac{m-1}{2}\,.\,\frac{m-2}{3}\,.\,nx^4-\ \&c.$$

For the sake of reference hereafter let this be called multiplication B.

Now for the same reasons as are stated in the 15th and 16th articles, the whole coefficient prefixed to any power of x in multiplication B, must be equal to the coefficient prefixed to the same power of x in the series $1-\overline{m+n}x+\overline{m+n}\,.\,\frac{m+n-1}{2}x^2-\overline{m+n}\,.\,\frac{m+n-1}{2}\,.\,\frac{m+n-2}{3}x^3+\overline{m+n}\,.\,\frac{m+n-1}{2}\,.\,\frac{m+n-2}{2}\,.\,\frac{m+n-3}{4}x^4-$ &c. ; and we are also at liberty to suppose n and m to be any two fractions whatever, in the series multiplied into one another, and consequently in the series expressing their product.

Proceeding therefore as in the 17th and 18th articles, and using the same notation, $\overline{1-x}|^{\frac{1}{r}} = 1 - \frac{1}{r}x + \frac{1}{r} . \frac{\frac{1}{r}-1}{2} x^2 - \frac{1}{r} . \frac{\frac{1}{r}-1}{2} . \frac{\frac{1}{r}-2}{3} x^3 + \frac{1}{r} . \frac{\frac{1}{r}-1}{2} . \frac{\frac{1}{r}-2}{3} . \frac{\frac{1}{r}-3}{4} x^4 -$ &c.

Also $\overline{1-x}|^{\frac{n}{r}} = 1 - \frac{n}{r}x + \frac{n}{r} . \frac{\frac{n}{r}-1}{2} x^2 - \frac{n}{r} . \frac{\frac{n}{r}-1}{2} . \frac{\frac{n}{r}-2}{3} x^3 + \frac{n}{r} . \frac{\frac{n}{r}-1}{2} . \frac{\frac{n}{r}-2}{3} . \frac{\frac{n}{r}-3}{4} x^4 -$ &c.

20. It is easily proved, by means of the 15th and 16th articles, that

$$\frac{\overline{1+x}|^{m}}{\overline{1+x}|^{n}} \text{ or } \frac{1+mx+m . \frac{m-1}{2} x^2 + m . \frac{m-1}{2} . \frac{m-2}{3} x^3 + m . \frac{m-1}{2} . \frac{m-2}{3} . \frac{m-3}{4} x^4 + \text{&c.}}{1+nx+n . \frac{n-1}{2} x^2 + n . \frac{n-1}{2} . \frac{n-2}{3} x^3 + n . \frac{n-1}{2} . \frac{n-2}{3} . \frac{n-3}{4} x^4 + \text{&c.}}$$

is equal to the series $1 + \overline{m-n}x + \overline{m-n} . \frac{m-n-1}{2} x^2 + \overline{m-n} . \frac{m-n-1}{2} . \frac{m-n-2}{3} x^3 + \overline{m-n} . \frac{m-n-1}{2} . \frac{m-n-2}{3} . \frac{m-n-3}{4} x^4 +$ &c whether m and n be whole numbers or fractions. For v being equal to $m-n$, this last series becomes $1 + vx + v . \frac{v-1}{2} x^2 + v . \frac{v-1}{2} . \frac{v-2}{3} x^3 + v . \frac{v-1}{2} . \frac{v-2}{3} . \frac{v-3}{4} x^4 +$ &c.; and this series being multiplied by $1 + nx + n . \frac{n-1}{2} x^2 + n . \frac{n-1}{2} . \frac{n-2}{3} x^3 + n . \frac{n-1}{2} . \frac{n-1}{3} . \frac{n-3}{4} x^4 +$ &c. the series expressing their product, by the 15th and 16th articles, is $1 + \overline{v+n}x + \overline{v+n} . \frac{v+n-1}{2} x^2 + \overline{v+n} . \frac{v+n-1}{2} . \frac{v+n-2}{3} x^3 + \overline{v+n} . \frac{v+n-1}{2} . \frac{v+n-2}{3} . \frac{v+n-3}{4} x^4 +$ &c. But as v is equal to $m-n$, this last series is equal to $1 + mx + m . \frac{m-1}{2} x^2 + m . \frac{m-1}{2} . \frac{m-2}{3} x^3 + m . \frac{m-1}{2} . \frac{m-2}{3} . \frac{m-3}{4} x^4 +$ &c.

Hence it is evident that $\frac{\overline{1+x}|^{m}}{\overline{1+x}|^{n}}$ is equal to $1 + \overline{m-n}x + \overline{m-n}$.

$\cdot\frac{m-n-1}{2}x^2+\overline{m-n}\cdot\frac{m-n-1}{2}\cdot\frac{m-n-2}{3}x^3+\overline{m-n}\cdot\frac{m-n-1}{2}\cdot\frac{m-n-2}{3}\cdot\frac{m-n-3}{4}x^4+$ &c.; and as this equation holds in every possible value of *m*, and as, by the general principles of involution $\overline{1+x}|^{0}$ is equal to 1, when *m* is equal to *o* then $\frac{1}{\overline{1+x}|^{n}}$, or $\overline{1+x}|^{-n}=1-nx-n\cdot\frac{-n-1}{2}x^2-n\cdot\frac{-n-1}{2}\cdot\frac{-n-2}{3}x^3-n\cdot\frac{-n-1}{2}\cdot\frac{-n-2}{3}\cdot\frac{-n-3}{4}x^4-$ &c.

According to the form of the binomial series, the whole of the second, fourth, sixth, &c. terms in the last series consist of an odd number of negative parts multiplied into one another, and therefore each of these terms becomes a negative quantity. But the whole of the third, fifth, seventh, &c. terms, consist of an even number of negative parts multiplied into one another, and therefore each of these terms becomes a positive quantity. Consequently, $\overline{1+x}|^{-n}=1-nx+n\cdot\frac{n+1}{2}x^2-n\cdot\frac{n+1}{2}\cdot\frac{n+2}{3}x^3+n\cdot\frac{n+1}{2}\cdot\frac{n+2}{3}\cdot\frac{n+3}{4}x^4-$ &c.

21. By the 19th article we are enabled to prove that

$$\frac{\overline{1-x}|^{m}}{\overline{1-x}|^{n}}\text{ or }\frac{1+m\cdot -x+m\cdot\frac{m-1}{2}x^2+m\cdot\frac{m-1}{2}\cdot\frac{m-2}{3}\cdot -x^3+m\cdot\frac{m-1}{2}\cdot\frac{m-2}{3}\cdot\frac{m-3}{4}x^4+\text{\&c.}}{1+n\cdot -x+n\cdot\frac{n-1}{2}x^2+n\cdot\frac{n-1}{2}\cdot\frac{n-2}{3}\cdot -x^3+n\cdot\frac{n-1}{2}\cdot\frac{n-2}{3}\cdot\frac{n-3}{4}x^4+\text{\&c.}}$$

is equal to the series $1+\overline{m-n}\cdot -x+\overline{m-n}\cdot\frac{m-n-1}{2}x^2+\overline{m-n}\cdot\frac{m-n-1}{2}\cdot\frac{m-n-2}{3}\cdot -x^3+\overline{m-n}\cdot\frac{m-n-1}{2}\cdot\frac{m-n-2}{3}\cdot\frac{m-n-3}{4}x^4+$ &c. For, as in the preceding article, if this last series be multiplied by $1+n\cdot -x+n\cdot\frac{n-1}{2}x^2+n\cdot\frac{n-1}{2}\cdot\frac{n-2}{3}\cdot -x^3+n\cdot\frac{n-1}{2}\cdot\frac{n-2}{3}\cdot\frac{n-3}{4}x^4+$ &c. the series expressing the product will be $1+m\cdot -x+m\cdot\frac{m-1}{2}x^2+m\cdot\frac{m-1}{2}\cdot\frac{m-2}{3}\cdot -x^3+m\cdot\frac{m-1}{2}\cdot$

$\frac{m-2}{3} . \frac{m-3}{4} x^4 +$ &c. Consequently as $\frac{\overline{1-x}|^m}{\overline{1-x}|^n} = 1 + \overline{m-n} . -x + \overline{m-n} . \frac{m-n-1}{2} x^2 + \overline{m-n} . \frac{m-n-1}{2} . \frac{m-n-2}{3} . -x^3 + \overline{m-n} . \frac{m-n-1}{2} . \frac{m-n-2}{3} . \frac{m-n-3}{4} x^4 +$ &c. in every possible value of m, it follows that when m is equal to o, then $\frac{1}{\overline{1-x}|^n}$ or $\overline{1-x}|^{-n} = 1 - n . -x - n . \frac{-n-1}{2} x^2 - n . \frac{-n-1}{2} . \frac{-n-2}{3} . -x^3 - n . \frac{-n-1}{2} . \frac{-n-2}{3} . \frac{-n-3}{4} x^4 -$ &c.

The form of this series, however, may be changed into one more convenient. For the whole of the second, fourth, sixth, &c. terms consist of an even number of negative parts multiplied into one another, and therefore each of these terms becomes a positive quantity. And as the coefficients of the third, fifth, seventh, &c. terms consist of an even number of negative parts multiplied into one another, and as in these terms the powers of x are positive, each of these terms becomes a positive quantity. Consequently $\overline{1-x}|^{-n} = 1 + nx + n . \frac{n+1}{2} x^2 + n . \frac{n+1}{2} . \frac{n+2}{3} x^3 + n . \frac{n+1}{2} . \frac{n+2}{3} . \frac{n+3}{4} x^4 +$ &c.

Every particular necessary for the establishment of the binomial theorem has now been proved. I therefore proceed to conclude the subject, by shewing that each of the four forms, in which the theorem may be expressed, immediately follows from the preceding articles, and the general principles of involution. In each of them n is to be considered either as a whole number or fraction.

22. By article 18, $\overline{1+x}|^n = 1 + nx + n . \frac{n-1}{2} x^2 + n . \frac{n-1}{2} . \frac{n-2}{3} x^3 + n . \frac{n-1}{2} . \frac{n-2}{3} . \frac{n-3}{4} x^4 +$ &c. But if $\frac{b}{a}$ be equal to x, then

$a^n \times \overline{1+\frac{b}{a}}\vert^n = \overline{a+b}\vert^n$, by the general principles of involution; and therefore $\overline{a+b}\vert^n = a^n \times : 1 + n\frac{b}{a} + n . \frac{n-1}{2}\frac{b^2}{a^2} + n . \frac{n-1}{2} . \frac{n-2}{3} . \frac{b^3}{a^3} + n . \frac{n-1}{2} . \frac{n-2}{3} . \frac{n-3}{4}\frac{b^4}{a^4} +$ &c. $= a^n + nba^{n-1} + n . \frac{n-1}{2} b^2 a^{n-2} + n . \frac{n-1}{2} . \frac{n-2}{3} b^3 a^{n-3} + n . \frac{n-1}{2} . \frac{n-2}{3} . \frac{n-3}{4} b^4 a^{n-4} +$ &c.

By article 19, $\overline{1-x}\vert^n = 1 - nx + n . \frac{n-1}{2} x^2 - n . \frac{n-1}{2} . \frac{n-2}{3} x^3 + n . \frac{n-1}{2} . \frac{n-2}{3} . \frac{n-3}{4} x^4 -$ &c. and therefore as before, if $\frac{b}{a}$ be equal to x, $\overline{a-b}\vert^n = a^n - nba^{n-1} + n . \frac{n-1}{2} ba^{n-2} - n . \frac{n-1}{2} . \frac{n-2}{3} b^3 a^{n-3} + n . \frac{n-1}{2} . \frac{n-2}{3} . \frac{n-3}{4} b^4 a^{n-4} -$ &c.

By article 20, $\overline{1+x}\vert^{-n} = 1 - nx + n . \frac{n+1}{2} x^2 - n . \frac{n+1}{2} . \frac{n-2}{3} x^3 + n . \frac{n+1}{2} . \frac{n+2}{3} . \frac{n+3}{4} x^4 -$ &c. and therefore if $\frac{b}{a}$ be equal to x, $\overline{1+\frac{b}{a}}\vert^{-n} = 1 - n\frac{b}{a} + n . \frac{n+1}{2}\frac{b^2}{a^2} - n . \frac{n+1}{2} . \frac{n+2}{3}\frac{b^3}{a^3} + n . \frac{n+1}{2} . \frac{n+2}{3} . \frac{n+3}{4}\frac{b^4}{a^4} -$ &c. But by the general principles of involution $\frac{1}{a^n \times \overline{1+\frac{b}{a}}\vert^n} = a^{-n} \times \overline{1+\frac{b}{a}}\vert^{-n} = \overline{a+b}\vert^{-n}$; and therefore $\overline{a+b}\vert^{-n} = a^{-n} - nba^{-n-1} + n . \frac{n+1}{2} b^2 a^{-n-2} - n . \frac{n+1}{2} . \frac{n+2}{3} b^3 a^{-n-3} + n . \frac{n+1}{2} . \frac{n+2}{3} . \frac{n+3}{4} b^4 a^{-n-4} -$ &c.

By article 21, $\overline{1-x}\vert^{-n} = 1 + nx + n . \frac{n+1}{2} x^2 + n . \frac{n+1}{2} . \frac{n+2}{3} x^3 + n . \frac{n+1}{2} . \frac{n+2}{3} . \frac{n+3}{4} x^4 +$ &c.; and therefore if $\frac{b}{a}$ be equal to x, $\overline{1-\frac{b}{a}}\vert^{-n} = 1 + n\frac{b}{a} + n . \frac{n+1}{2}\frac{b^2}{a^2} + n . \frac{n+1}{2} . \frac{n+2}{3}\frac{b^3}{a^3} + n . \frac{n+1}{2} . \frac{n+2}{3} . \frac{n+3}{4}\frac{b^4}{a^4} +$ &c. But by the general principles of involution $\frac{1}{x^n \times \overline{1-\frac{b}{a}}\vert^n} = a^{-n} \times \overline{1-\frac{b}{a}}\vert^{-n} = \overline{a-b}\vert^{-n}$; and therefore $\overline{a-b}\vert^{-n} =$

$$a^{\overline{-n}} + nba^{\overline{-n-1}} + n.\frac{n+1}{2}b^2a^{\overline{-n-2}} + n.\frac{n+1}{2}.\frac{n+2}{3}b^3a^{\overline{-n-3}} + n.\frac{n+1}{2}.\frac{n+2}{3}.\frac{n+3}{4}b^4a^{\overline{-n-4}} + \&c.$$

The four forms expressed in this article include the whole of the binomial theorem.

XVI. *New Method of computing Logarithms. By* Thomas Manning, *Esq. Communicated by the Right Hon. Sir* Joseph Banks, *K. B. P. R. S.*

Read June 5, 1806.

If there already existed as full and extensive logarithmic tables as will ever be wanted, and of whose accuracy we were absolutely certain, and if the evidence for that accuracy could remain unimpaired throughout all ages, then any new method of computing logarithms would be totally superfluous so far as concerns the formation of tables, and could only be valuable indirectly, inasmuch as it might shew some curious and new views of mathematical truth. But this kind of evidence is not in the nature of human affairs. Whatever is recorded is no otherwise believed than on the evidence of testimony; and such evidence weakens by the lapse of time, even while the original record remains; and it weakens on a twofold account, if the record must from time to time be replaced by copies. Nor is this destruction of evidence arising from the uncertainty of the copy's being accurately taken, any where greater than in the case of copied numbers.

It is useful then to contrive new and easy methods for computing not only new tables, but even those we already have. It is useful to contrive methods by which any part of a table may be verified independently of the rest; for by examining parts taken at random, we may in some cases satisfy ourselves of its accuracy, as well as by examining the whole.*

Among the various methods of computing logarithms, none, that I know of, possesses this advantage of forming them with tolerable ease independently of each other by means of a few easy bases. This desideratum, I trust, the following method will supply, while at the same time it is peculiarly easy of application, requiring no division, multiplication, or extraction of roots, and has its relative advantages highly increased by increasing the number of decimal places to which the computation is carried.

The chief part of the working consists in merely setting down a number under itself removed one or more places to the right, and subtracting, and repeating this operation; and consequently is very little liable to mistake. Moreover, from the commodious manner in which the work stands, it may be revised with extreme rapidity. It may be performed after a few minutes instruction by any one who is competent to subtract. It is as easy for large numbers as for small; and on an average about 27 subtractions will furnish a logarithm acccurately to 10 places of decimals. In general $9\times\frac{n+1}{2}$ subtractions will be accurate to $2n$ places of decimals.

In computing hyperbolic logarithms by this method it is necessary to have previously establised the h. logs. of $\frac{10}{9}$, $\frac{100}{99}$, $\frac{1000}{999}$, &c. of 2 and of 10.

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* For example, we may wish to know whether the editor of a table has been careless. We examine detached portions here and there to a certain extent; if we find no errors, we have a moral certainty that the editor was careful, and consequently a moral certainty that the edition is accurate.

With respect to the logs. of $\frac{10}{9}$, $\frac{100}{99}$, $\frac{1000}{999}$, &c. their computation is very easy,* they being the respective sums of the series

$$\frac{1}{10} + \frac{1}{2} \times \frac{1}{\overline{10}|^{2}} + \frac{1}{3} \times \frac{1}{\overline{10}|^{3}} + \frac{1}{4} \times \frac{1}{\overline{10}|^{4}} + \&c.$$

$$\frac{1}{100} + \frac{1}{2} \times \frac{1}{\overline{100}|^{2}} + \frac{1}{3} \times \frac{1}{\overline{100}|^{3}} + \frac{1}{4} \times \frac{1}{\overline{100}|^{4}} + \&c.$$

$$\frac{1}{1000} + \frac{1}{2} \times \frac{1}{\overline{1000}|^{2}} + \frac{1}{3} \times \frac{1}{\overline{1000}|^{3}} + \&c.$$

&c.

of which series each is more easily summed than the preceding.

With respect to the logarithms of 2 and 10 there are, it is well known, various ways of computing them, and the time requisite depends greatly on the practical habits of the calculator. Among other ways, they may be computed by the method given in this Paper, and with what degree of expedition, may be seen by the examples to the rules, where they are both of them worked.†

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* Ex. H. l. $\frac{1000}{999} = \frac{1}{1000} + \frac{1}{2} \times \frac{1}{\overline{1000}|^{2}} + \frac{1}{3}\frac{1}{\overline{1000}|^{3}} + \&c.$

1st term = ,001
2d term = ,0000005
3d term = ,000000000333

Sum = ,001000500333, which is true to the last place of decimals.

† It may be seen there that the logarithm of 10 by this method requires very little work. The log. of 2 may also be computed from the log. of 10 as follows.

$2^{10} = 1024 = 1000 \times \left(1 + \frac{24}{1000}\right)$ therefore log. $2^{10} = 3 \times$ log. $10 +$ log. $\left(1 + \frac{24}{1000}\right) = 3 \times$ log. $10 + \left(\frac{24}{1000} - \frac{1}{2}\frac{\overline{24}|^{2}}{\overline{1000}|^{2}} + \frac{1}{3} \times \frac{\overline{24}|^{3}}{\overline{1000}|^{3}} - \&c.\right)$

TABLE, *containing the hyperbolic Logarithms of* $\frac{10}{9}$, $\frac{100}{99}$, $\frac{1000}{999}$, *&c. of* 2 *and of* 10; *together with the Reciprocal of the last or Modulus of the common Logarithms.*

H. l. of $\frac{10}{9}$ = ,105360515655

h. l. $\frac{100}{99}$ = ,010050335853

h. l. $\frac{1000}{999}$ = ,001000500333

h. l. $\frac{10000}{9999}$ = ,000100005 . .

h. l. $\frac{100000}{99999}$ = ,00001000005

h. l. $\frac{1000000}{999999}$ = ,000001

h. l. $\frac{10000000}{9999999}$ = ,0000001

h. l. $\frac{100000000}{99999999}$ = ,00000001

$1000)24(.024$
$\times 2$
48
$\times 12$
$2\times\overline{1000}|^2\ )576(.000288$
$\times 2$
1152
$\times 12$
$3\times\overline{1000}|^3\ )13824(.000004608$
$\times 2$
27648
$\times 12$
$4\times\overline{1000}|^4\ )331776(.00000008294\overline{4}$
$\times 2$
663452
$\times 12$
$5\times\overline{1000}|^5\ )7962624(.00000000159\overline{2}$

Sum of odd terms ,024004609592
—— even —— ,000288082944
Difference ,023716526648
3× log. 10 6.907755279648
Log. 2^{10} - - 6,931471806296. True to the 10th figure.

and so on; the unit receding regularly to the right.

h. l. 2 = ,693147180637
h. l. 10 = 2,302585093217
$\frac{1}{\text{h. l. 10}}$ = ,434294481861.

Certain Multiples of the above Numbers; viz. all those required in computing Logarithms by the subjoined Rules, and which are not evident upon Inspection.

Multiples of the h. logs. of $\frac{10}{9}$, $\frac{100}{99}$, &c.		Multiples of h. l. 2, h. l. 10, and $\frac{1}{\text{h. l. 10}}$.	
		Of h. l. 2.	
Double h. l. of $\frac{10}{9}$	= ,210721031310	Double	=1,386294361274
triple	= ,316081546965	triple	=2,079441541911
quadruple	= ,421442062620	quadple.	=2,772588722548
5ple.	= ,526802578275	5ple.	=3,465735903185
6ple.	= ,632163093930	6ple.	=4,158883083822
7ple.	= ,737523609585	7ple.	4,852030264459
8ple.	= ,842884125240	8ple.	5,545177445096
9ple.	= ,948244640895	9ple.	6,238324625733
		Of h. l. 10	
Double h. l. $\frac{100}{99}$	= ,020100671706	Double	=4,605170186434
triple	,030151007559	triple	=6,907755279651
quadruple	,040201343412	quadple.	9,210340372868
5ple.	,050251679265	5ple.	11,512925466085
6ple.	,060302015118	6ple.	13,815510559302
7ple.	,070352350971	7ple.	16,118095652519
8ple.	,080402686824	8ple.	18,420680745736
9ple.	,090453022677	9ple.	20,723265838953
		Of $\frac{1}{\text{h. l. 10}}$.	
Double h. l. $\frac{1000}{999}$	= ,002001000666	Double	= ,868588963722
triple	= ,003001500999	triple	=1,302883445583
quadruple	= ,004002001332	quadple.	=1,737177927444
5ple.	= ,005002501665	5ple.	=2,171472409305
6ple.	= ,006003001998	6ple.	=2,605766891166
7ple.	= ,007003502331	7ple.	=3,040061373027
8ple.	= ,008004002664	8ple.	=3,474355854888
9ple.	= ,009004502997	9ple.	=3,908650336749

I. *To find the hyperbolic Logarithm of any Number not exceeding 2.*

RULE. Set the number under itself, to be subtracted from itself, but removed so many places to the right as shall be necessary to make the remainder greater than 1; subtract. Proceed in the same manner with the remainder, and so on till the remainder becomes 1 followed by $\frac{1}{2}$ as many cyphers as the number of decimal places you work to; suppose at the end of the operation you find that you have removed *one* place to the right and subtracted b times; *two* places, c times; three places, d times, &c.; then $b \times \text{h. l.} \frac{10}{9} + c \times \text{h. l.} \frac{100}{99} + d \times \text{h. l.} \frac{1000}{999} + \text{\&c.} +$ decimal part of the last remainder = h. l. sought.

And these numbers are collected together out of the Table; for b, c, d, &c. can none of them ever exceed 9.

Ex. 1. *To find the h. l. of 2 to 10 Places of Decimals.*

$$\begin{array}{l}
2. \\
\underline{.2} \\
1.8 \\
\underline{.18} \\
1.62 \\
\underline{162} \\
1.458 \\
\underline{.1458} \\
1.3122 \\
\underline{13122} \\
1.18098 \\
\underline{118098} \\
1.062882 \ldots\ldots 6 \\
\underline{1062882} \\
1.05225318 \\
\underline{105225318} \\
1.0417306482 \\
\underline{10417306482} \\
1.031313341718 \\
\underline{103131334171} \\
1.0210002083009 \\
\underline{102100020830} \\
1.0107902062179 \\
\underline{101079020621} \\
1.0006823042558 \ldots\ldots 6.
\end{array}$$

$$6 \times \text{h. l.} \frac{10}{9} = .632163093980$$

$$6 \times \text{h. l.} \frac{100}{99} = .060302015118$$

$$6 \times \text{h. l.} \frac{10000}{9999} = .00060003\ldots$$

$$8 \times \text{h. l.} \frac{\overline{10|}^{5}}{99999} = .0000800004\ldots$$

$$2 \times \text{h. l.} \frac{\overline{10|}^{6}}{999999} = .000002\ldots\ldots$$

$$\text{decim. last rem.} = \underline{.000000041189}$$

$$\underline{\text{h. l. } 2 = 693147180637}$$

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1.0006823042558
1000682304

1.0005822360254
1000582236

1.0004821778018
1000482177

1.0003821295841
1000382129

1.0002820913712
1000282091

1.0001820631621
1000182063

1.0000820449558 6
100008204

1.0000720441354
100007204

1.0000620434150
100006204

1.0000520427946
100005204

1.0000420422742
100004204

1.0000320418538
100003204

1.0000220415334
100002204

1.0000120413130
100001204

1.0000020411926 8
10000020

1.0000010411906
10000010

1.0000000411896 Last remainder.

Ex. II. *To find the h. l. of 1.25.*

1.25
125
1.125
.1125
1.0125 2
10125
1.002375 1
1002375
1.001372625
1001372625
1.000371252375 2
1000371252
1.000271215249
1000271215
1.0001711881283
1000171188
1.0000711710095 3
100007117
1.0000611702978
100006117
1.0000511696861
100005116
1.0000411691745
100041116
1.0000311687629
100003116
1.0000211684513
100002116
1.0000111682397
100001116
1.0000011681281 7
10000011
1.0000001681270 last remainder.

$2 \times$ h. l. $\frac{10}{9}$ .... ,210721031310
$1 \times$ h. l. $\frac{100}{99}$ .... ,010050335853
$2 \times$ h. l. $\frac{1000}{999}$ .... ,002001000666
$3 \times$ h. l. $\frac{\overline{10|}^{4}}{9999}$ .... ,000300015000
$7 \times$ h. l. $\frac{\overline{10|}^{5}}{99999}$ .... ,000070000350
$1 \times$ h. l. $\frac{\overline{10|}^{6}}{999999}$ .... ,000001 ......
decimal of last remainder .... ,000000168127

log. required .... ,223143551306

II. *To find the h. l. of any Number, whole or mixt.*

RULE. Reduce the given number (if necessary) to a whole or mixt number less than 2, by setting the decimal point after the first significant figure, or if the given number be 10 or a power of 10 after the first 0; and then dividing by 2 (if necessary) till the integral part is 1.*

Find the h. l. of this reduced number by the last rule, and add to it or subtract from it as many times the h. l. of 10 as the decimal point was removed places to the left or right; also add to it as many times the h. l. of 2 as there were divisions by 2. The sum is the h. l. required.

Ex. III. *To find the h. l. of* 10.

$\frac{10}{2^3}$ = 1.25, whose h. log. is found in the last example to be

,223143551306
h. l. 2^3 = 2,079441541911
h. l. 10 2,302585093217

Ex. IV. *To find the h. l. of* 5548748 *to* 6 *Places of Decimals.*

4)5.548748
1.387187
1387187
1.2484683
12484683
1.12362147
112362147
1.011259323 . . . 3
10112593
1.001146730 . . . 1
1001146
1.000145584 last remainder.

$3 \times$ h. l. $\frac{10}{9}$ = ,316081546
$1 \times$ h. l. $\frac{100}{99}$ = ,010050335
$1 \times$ h. l. $\frac{1000}{999}$ = ,001000500
decimal of last remainder = ,000145584
h. log. 1.387187 = ,327277965
$6 \times$ h. l. 10 = 13,815510559
$2 \times$ h. l. 2 = 1,386294361
log. required 15,529082885

---

* Three divisions by 2 will always suffice.

Ex. v. *To find the h. l. of 7 to 5 Places of Decimals.*

	4)7.	
	1.75	$5 \times$ h. l. $\frac{10}{9}$ … ,5268025
	175	
	1.575	$3 \times$ h. l. $\frac{100}{99}$ … ,0301510
	1575	
	1.4175	$2 \times$ h. l. $\frac{1000}{999}$ … ,0020010
	14175	
	1.27575	decim^l of last rem^r … ,0006614
	127575	$2 \times$ h. l. 2 … 1,3862943
	1.148175	log. 7 = 1,9459102
	1148175	
5 …..	1.0333575	
	1033357	
	1.02302393	
	1023023	
	1.01279370	
	1012793	
3 …..	1.00266577	
	100266	
	1.00166311	
	100166	
last rem.	1.00066145	

From the small number of subtractions that have been necessary, the log. of 7 must be correct to 6 places of decimals.

III. *To find the common Logarithm of any Number.*

Rule. Find the h. l. by the above rule, and multiply $\frac{1}{\text{h. l. } 10}$ into it.

Otherwise. Proceed by art. 2, omitting what concerns the

h. l. 10. Multiply into $\frac{1}{\text{h. l. } 10}$, and add or subtract as many units as the decimal point was removed to the left or right.

Note. The multiplication of a number by $\frac{1}{\text{h. l. } 10}$ is very expeditiously performed by means of the Table of multiples of $\frac{1}{\text{h. l. } 10}$.

The demonstration of the above rules is obvious. Setting the figures of a number one place to the right is dividing that number by 10; 2 places, by 100; 3 places, by 1000; and so on. And subtracting a number, so placed, from the number itself is subtracting a 10th, a 100th, a 1000th, &c. (in the respective cases) of the number from itself; and consequently the remainders are (respectively) $\frac{9}{10}$ths, $\frac{99}{100}$ths, $\frac{999}{1000}$ths, &c. of the numbers subtracted from. Let *b*, *c*, *d*, &c. denote as in the rule; then the original number $= \overline{\tfrac{10}{9}}\big|^{b} \times \overline{\tfrac{100}{99}}\big|^{c} \times \overline{\tfrac{1000}{999}}\big|^{d} \times$ &c. $\times$ last remainder. Therefore the log. of the original number $= b \times \text{log.}\ \frac{10}{9} + c \times \text{log.}\ \frac{100}{99} + d \times \text{log.}\ \frac{1000}{999} +$ &c. $+$ log. of last remainder. Now the last remainder being unity followed by a certain number of decimal cyphers, its correct hyp. log., as far as twice that number of places, is (as is well known) the decimal part itself of that remainder. Hence the rule is manifest.

A similar method, by addition only, by means of the ready computed logarithms of $\frac{11}{10}$, $\frac{101}{100}$, $\frac{1001}{1000}$, &c. might, in some cases, be used with advantage. Let N denote the given number, consisting of unity and a decimal whose h. l. is sought; and let P denote any number less than N, and whose h. l. is previously known. Set P under itself removed one or more places to the right; add; and proceed with the sum in the same manner, till you have obtained a number, $N \pm a$, the difference between which and N shall be inconsiderable. Let b, c, d, &c. denote as in the rule.

Then $P \times \overline{\tfrac{11}{10}}|^{b} \times \overline{\tfrac{101}{100}}|^{c} \times \overline{\tfrac{1001}{1000}}|^{d} \times \text{\&c.} = N \pm a.$

Therefore $\log. \overline{N \pm a} = \log. P + b \times \log. \tfrac{11}{10} + c \times \log. \tfrac{101}{100}$ $+ d \times \log. \tfrac{1001}{1000} + \text{\&c.}$, which call B.

And $\log. N = \log. \frac{N}{N \pm a} + \log. \overline{N \pm a} = \log. \frac{N}{N \pm a} + B.$

Now we may either carry the operation so far that $\log. \frac{N}{N \pm a}$ may be neglected, or we may actually divide N by $N - a$, or $N + a$ by N (according as the sign is $-$ or $+$) and add or subtract the quotient from B.

Various artifices may be occasionally used to shorten the computation both in the method of subtraction, and in this of addition; and the two may sometimes be advantageously combined together.

It should be observed that, in setting down the numbers, the last figure set down ought to be increased by unity when the figure immediately following in the neglected part exceeds 4.

EXAMPLE *of the Method of Addition.* *To find the h. l. of* 2.

$$\begin{array}{r}
1.1 \\
11 \\ \hline
1.21 \\
121 \\ \hline
1.331 \\
1331 \\ \hline
1.4641 \\
14641 \\ \hline
1.61051 \\
161051 \\ \hline
1.771561 \\
177156 \\ \hline
1.948717 \\
19487 \\ \hline
1.968204 \\
19682 \\ \hline
1.987886 \\
1988 \\ \hline
1.989874 \\
1989^{*} \\ \hline
1,991863
\end{array}$$

Continued.

$$\begin{array}{r}
1.991863 \\
1992 \\ \hline
1.993855 \\
1994 \\ \hline
1.995849 \\
1996 \\ \hline
1.997845 \\
1998 \\ \hline
1.999843 \\
199 \\ \hline
2.000042 \\ \hline
\end{array}$$

From this operation it appears, that

$\frac{11}{10} \times \overline{\frac{11}{10}}^{6} \times \overline{\frac{101}{100}}^{2} \times \overline{\frac{1001}{1000}}^{6} \times \frac{10001}{10000} = 2.000042.$

Consequently, $7 \times$ h.l. $\frac{11}{10} + 2 \times$ h.l. $\frac{101}{100} + 6 \times$ h.l. $\frac{1001}{1000} +$ h.l. $\frac{10001}{10000} =$ h. l. 2,000042.

$=$ h. l. 2 $+$ h. l. $\frac{2.000042}{2} =$ h. l. 2 $+$ h. l. $(1.000021) =$ h. l. 2 $+$ 000021.

The method by subtraction has many advantages over this by addition. It is more simple, and being more completely mechanical, may be confided to the most unskilful without danger of error. And though addition be an easier operation than subtraction, yet the greater facility arising from this circumstance will not be found sufficient to balance these and other advantages.

---

* Instead of this number 1989, it would be more correct to set down 1990, because the first figure of the neglected part, 874, exceeds 4.

XVII. *Description of the Mineral Bason in the Counties of Monmouth, Glamorgan, Brecon, Carmarthen, and Pembroke. By Mr.* Edward Martin. *Communicated by the Right Hon.* C. F. Greville, *F. R. S.*

Read May 22, 1806.

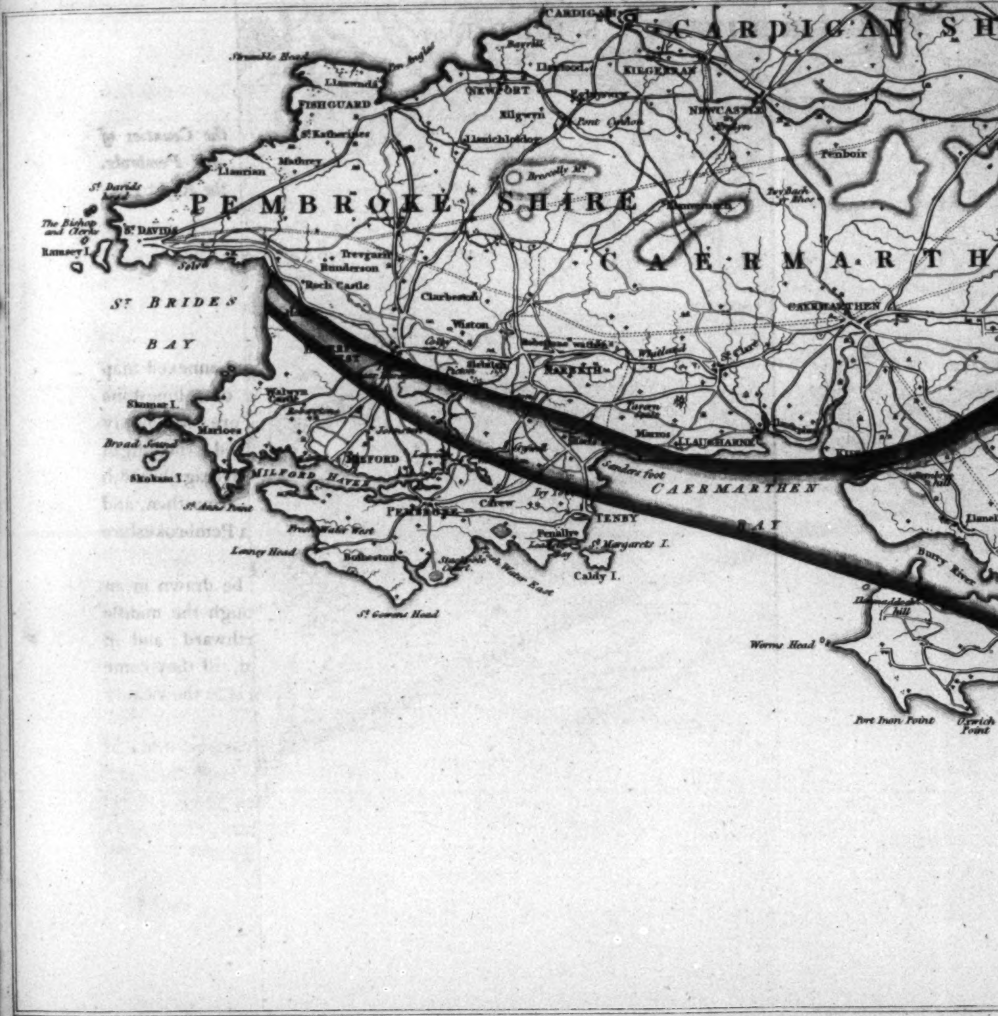
1. THE irregular oval line, delineated on the annexed map (Plate XIV.) shows nearly the inner edge of a limestone bason, in which all the strata of coal and iron ore (commonly called Iron Stone) in South Wales are deposited; the length of this bason is upwards of 100 miles, and the average breadth in the counties of Monmouth, Glamorgan, Carmarthen, and part of Brecon, is from 18 to 20 miles, and in Pembrokeshire only from 3 to 5 miles.

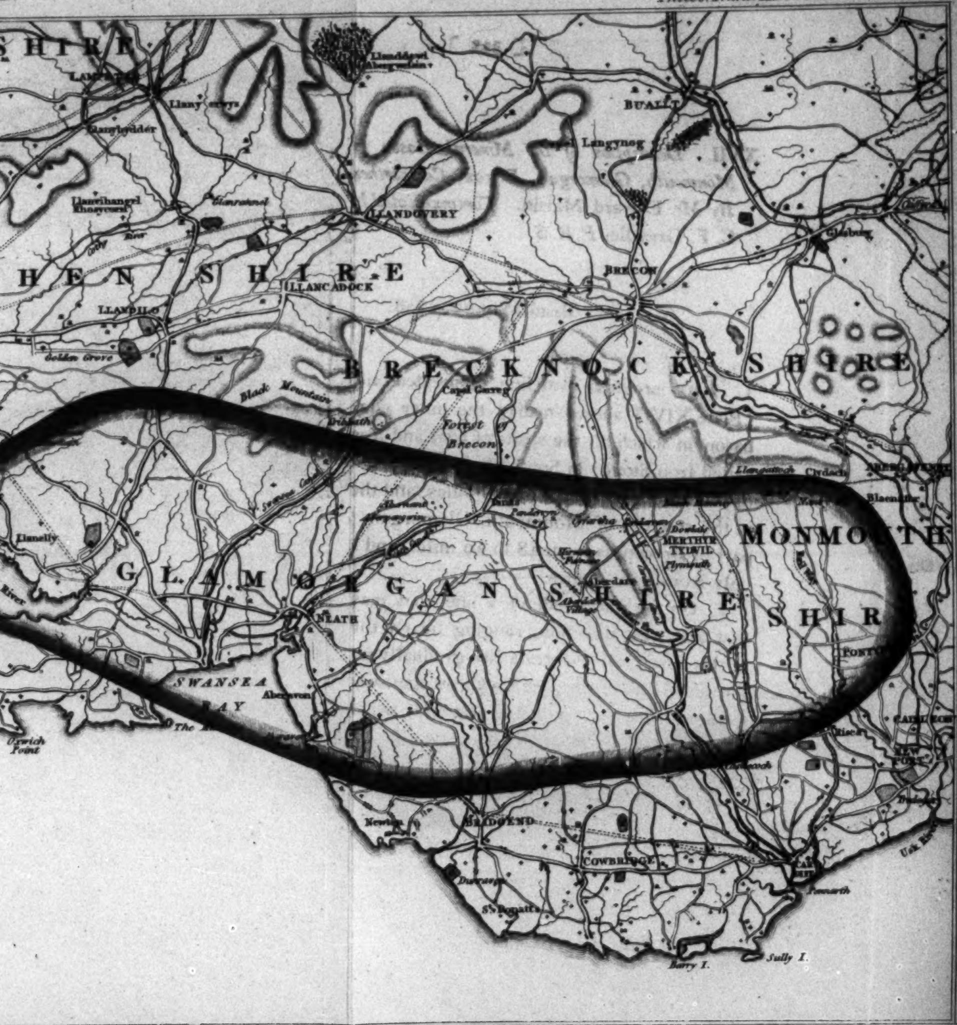
2. On the north side of a line, that may be drawn in an east and west direction, ranging nearly through the middle of this bason, all the strata rise gradually northward; and on the south side of this line they rise southward, till they come to the surface, except at the east end, which is in the vicinity of Pontipool, where they rise eastward.

3. The depths from the surface to the various strata of coal and iron ore depend upon their respective local situations.

4. The deepest part of the bason is between Neath, in Glamorganshire, and Llanelly, in Carmarthenshire; the uppermost stratum of coal here does not extend a mile in a north

N° 1.


CARDIGAN SH
PEMBROKE SHIRE
CAERMARTH
Strumble Head
Fishguard
Newport
Llanwnda
St Katherines
Mathrey
Llanrian
St Davids head
The Bishop and Clerks
Ramsey I.
St Davids
Solva
St Brides Bay
Skomar I.
Broad Sound
Skokam I.
Marloes
Walwyn Castle
St Anns Point
Milford Haven
Pembroke
Frest Water West
Linney Head
Bosheston
St Gowens Head
Stackpole Court
Tenby
Penallye
St Margarets I.
Caldy I.
Saunders foot
Caermarthen Bay
Laugharne
Marros
Whitland
St Clare
Narberth
Clarbeston
Wiston
Roch Castle
Tregarn
Brimderson
Kilgerran
Newcastle
Penboir
Llanichloddog
Kilgwyn
Precelly Mt
Caermarthen
Llanelly
Burry River
Worms Head
Port Inon Point
Oxwich Point
Cardigan


SHIRE
LAMPETER
Llanyerwys
Llanybydder
Llanddewi Abergwessin
BUALLT
Capel Langynog
Llanvihangel Rhosycorn
Glanrannel
Cothy River
LLANDOVERY
Glasbury
HENSHIRE
LLANCADOCK
BRECON
LLANDILO
Golden Grove
BRECKNOCKSHIRE
Black Mountain
Capel Garreg
Forest of Brecon
Llangattock
Clydach
Blaenafon
Swansea Canal
Llanelly
Aberdare
MERTHYR TYDVIL
Plymouth
MONMOUTHSHIRE
GLAMORGANSHIRE
NEATH
Aberdare Village
PONTYPOOL
SWANSEA BAY
Aberavon
Orwich Point
CAERLEON
NEW PORT
Risca
Newton
BRIDGEND
COWBRIDGE
Dunraven
St. Donatts
CARDIFF
Penarth
Barry I.
Sully I.
Usk River

Basire fc.

and south direction, and not many miles in an east and west direction, and its utmost depth is not above 50 or 60 fathoms.

5. The next stratum of coal, and those likewise beneath it, lie deeper and expand still longer and wider, and the lowest which are attended by parallel strata of iron ore, of which there are in some situations about 16 accompanied by irregular balls or lumps of iron ore, occupy the whole space between Llanmaddock Hill, near the entrance of Burry river, to Llanbidie, from the Mumbles to Cribbath, from Newton Down to Penderryn, from Castle Coch to Castle Morlais, and from Risca to Llangattock, and in length on the south side of the bason from Pontypool through Risca, Tinkwood, Llantrissent, Margam, Swansea Bay, and Cline Wood, to Llanmaddock Hill, and on the north side through Blaenafon, Ebbw, Sirhowy, Merthyr, Aberdare, Aberpergwm, Glyntowy, Llandibie, and the Great Mountain, to Pembrey Hill, near Llanelly in Carmarthenshire, and their depths are at the centre range of strata from 6 to 700 fathoms.

6. The strata of coal and iron ore running from Pembrey Hill, through Carmarthen Bay and Pembrokeshire to St. Bride's Bay, are only a continuation of those in the counties of Glamorgan and Carmarthen, which lie next to and parallel with the north side of the bason, all the remaining strata rising southward; and the middle ranges on the north side of the bason, are lost between where they meet the sea near Llanmaddock Hill and the south side of Pembrey Hill, in their course towards Pembrokeshire, in consequence of a contraction of the sides of the mineral bason, or rather by its becoming shallower; for in Pembrokeshire none of the strata of coal or iron ore lie above 80 or 100 fathoms deep, consequently

all those which do not lie above 5 or 600 fathoms in Glamorganshire and Carmarthenshire have not reached this county, by reason of the bason not being of sufficient depth and width to hold them.

7. The strata of coal at the east end of the bason running from Pontypool to Blaenafon and Clydach, and on the north side from thence to Nanty Glo, Ebbw, Beaufort, Sirhowy, Tredegar, Romney, Dowlais, Penderryn, Plymouth, Cyfarthfa, Abernant, Aberdare and Hurwain Furnaces and Iron Works, are of a cokeing quality, and from thence the whole strata of coal to St. Bride's Bay alter in their quality, to what is called Stone Coal, (the large of which has hitherto been used for the purposes of drying malt and hops, and the small, which is called Culm, for burning of limestone); the several strata of coal from Pontypool, on the south side of the bason, through Risca, Llantrissent, Margam, and Cline Wood, to Burry River, Llanelly, and the south side of Pembrey Hill, are principally of a bituminous or binding quality.

8. Notwithstanding the principal strata of coal in Glamorganshire, lie from 5 fathoms to 6 or 700 fathoms deep, still it has not been necessary to pursue these strata deeper than about 80 fathoms.

9. The veins of coal and iron ore, in the vicinity of most of the iron works in Monmouthshire and Glamorganshire are drained and worked by levels or horizontal drifts, which opportunity is given by the deep valleys which generally run in a north and south direction, intersecting the range of coal and iron ore, which run in an east and west direction, under the high mountains, and thereby serving as main drains, so that the collier or miner here gets at the treasures of the

earth, without going to the expence and labour of sinking deep pits, and erecting powerful fire-engines. However, in process of time, in situations where the coal and iron ore that are above the level of these natural drains, become exhausted, it will be found necessary to sink shallow pits, and erect fire-engines for the draining and working of the coal and iron ore, and at a future period, pits of greater depths, must be sunk for the same purposes.

10. There are 12 veins or strata of coal in this mineral depository, from 3 feet to 9 feet thick each; which together make 70½ feet: and there are 11 more, from 18 inches to 3 feet, which make 24¼ feet, making in all 95 feet; besides a number of smaller veins from 12 to 18 inches, and from 6 to 12 inches in thickness, not calculated upon.

11. By taking the average length and breadth of the foregoing different strata of coal, the amount is about 1000 square miles, containing 95 feet of coal in 23 distinct strata, which will produce in the common way of working 100,000 tons *per* acre, or 64,000,000 tons *per* square mile.

12. If the whole extent of this mineral country was an even plain, the border or outbreak of each stratum would appear regular and true; but owing to the interposition of hills and valleys, the edges of the strata, if nicely measured and planned, would seem indented and uneven, yet in many instances the due range is totally thrown out of course, in consequence of knots, dikes, or faults.

13. These faults or irregularities are not confined to the edges of the strata, but they take grand ranges, through the interior of the bason, generally in a north and south direction, and often throw the whole of the strata, for hundreds of acres

together, 40, 60, 80, or 100 fathoms, up or down, and still there is seldom any superficial appearance, that indicates a disjunction, for the largest faults frequently lie under even surfaces.

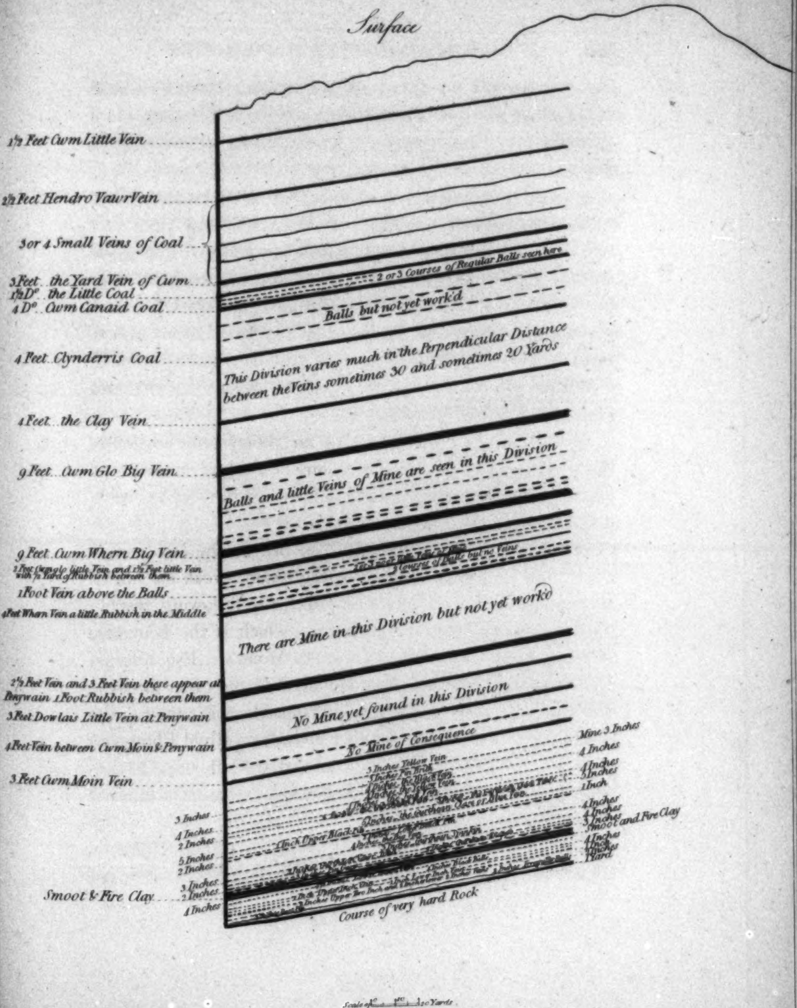
14. As every stratum rises regularly from its base to the surface, and is frequently visible and bare, in precipices and deep dingles, and often discovered where the earth or soil is shallow in trenching, or in forming high roads, and by reason of the whole of the country within this boundary being so perforated by pits, and so intersected by the various operations of art and nature, it is not probable that any vein of coal, iron ore, or other stratum remains undiscovered in this mineral bason.

15. Glamorganshire engrosses far the greatest portion of coal and iron ore, Monmouthshire the next in point of quantity, Carmarthenshire the next, Pembrokeshire the next, and Brecknockshire possesses the least.

16. The strata of coal and iron ore in the last named county, which are the lowest in the bason, break out northward, and only take place in the three following distinct spots, *viz.* 1st. From Turch River (which is the boundary between Lord CAWDOR and CHARLES MORGAN, Esq.) across the river Tawe and the Drin Mountain to the great forest of Brecon. 2d. A corner of ground from Blaen Romney to the north of Brynoer. 3d. Another spot, from Rhyd Ebbw and Beaufort Iron Works, through Llwyn y Pwll, near Tavern Maed Sur, to where it joins Lord ABERGAVENNY'S mineral property.

17. *Note.* A principal fault is observable at Cribbath, where the beds or strata of the limestone stand erect: another,

No. 2


Surface
1½ Feet Cwm Little Vein
2½ Feet Hendro Vawr Vein
3 or 4 Small Veins of Coal
3 Feet the Yard Vein of Cwm
1½ Do. the Little Coal
4 Do. Cwm Canaid Coal
2 or 3 Courses of Regular Balls seen here
Balls but not yet work'd
4 Feet Clynderris Coal
This Division varies much in the Perpendicular Distance between the Veins sometimes 30 and sometimes 20 Yards
4 Feet the Clay Vein
9 Feet Cwm Glo Big Vein
Balls and little Veins of Mine are seen in this Division
9 Feet Cwm Whern Big Vein
2 Feet Cwm glo little Vein and 1½ Feet little Vein with ½ Yard of Rubbish between them
3 Courses of Balls but no Veins
1 Foot Vein above the Balls
4 Feet Whern Vein a little Rubbish in the Middle
There are Mine in this Division but not yet work'd
2½ Feet Vein and 3 Feet Vein these appear at Penywain 1 Foot Rubbish between them
3 Feet Dowlais Little Vein at Penywain
No Mine yet found in this Division
4 Feet Vein between Cwm Moin & Penywain
No Mine of Consequence
3 Feet Cwm Moin Vein
Mine 3 Inches
4 Inches
3 Inches Yellow Vein
4 Inches
3 Inches
1 Inch
4 Inches
4 Inches
3 Inches
Smoot and Fire Clay
4 Inches
1 Inch
3 Inches
Hard
3 Inches
4 Inches
2 Inches
1 Inch Upper Black Pin
5 Inches
2 Inches
3 Inches
2 Inches
Smoot & Fire Clay
4 Inches
Course of very hard Rock
Scale of 10 20 Yards

of considerable magnitude, lies between Ystradvellte and Penderryn, where all the strata on the north side of the bason are moved many hundreds of yards southward (as at Dinas).

18. *Note.* The limestone appears to the surface all along the boundary line in the counties of Monmouth, Glamorgan, Carmarthen, Brecon, and no doubt can be entertained of its due range from Newton across Swansea Bay to the Mumbles, and from Llanmaddock Hill across Carmarthen Bay to Tenby. In Pembrokeshire it appears to the surface on the south side of the bason, at Tenby, Ivy Tower, Cochelard, Bit Church, Williamston, Lawrinny, Cord, Canta, and Johnston; and on the north side of the bason, at Templeton, Picton, Harriston, and Persfield; yet it certainly forms an underground connection from point to point.

XVIII. *Observations on the Permanency of the Variation of the Compass at Jamaica. In a Letter from Mr.* James Robertson *to the Right Hon. Sir* Joseph Banks, *K. B. P. R. S. &c.*

Read June 12, 1806.

SIR,

As any improvement, or discovery in the arts and sciences, will, I am persuaded, experience your favourable reception, I have the honour of submitting to your consideration a discovery I have made on a subject, the state of which can only be ascertained by observations made from time to time, as it is not regulated by any known law of nature: I mean the variation of the magnetical needle.

This discovery may not only excite others to make, and repeat, observations in different parts of the globe, but, by causing this changeable quality to be better understood, may contribute to the benefit of navigation, and commerce, as well as to the advancement of a more particular knowledge of the subject.

It has hitherto been considered, that the variation of the magnetical needle is not fixed in any particular place, but is constantly varying, in a greater or a less degree, in all parts of the world. I have discovered an exception to this supposed general property of variation; and, as it may be, perhaps, the first that has been made, it will require proportionally strong proof to establish it. This, I flatter myself, I am able to effect, to the certainty of demonstration itself: but, in doing so, I am under the necessity of being more tedious than I could wish, in order to describe fully the data, on which the inference is founded.

I resided at Jamaica, as a King's Surveyor of Land, upwards of 20 years. Disputes at law about boundaries of lands are there decided by ejectments, in the Supreme Court of Judicature, by the evidence and diagrams of King's surveyors of land. This is different from the practice in England, because the manner in which grants of land from the Crown are made, in the two countries is different. In Jamaica, to every grant of land a diagram thereof is annexed to the patent. This diagram is delineated from an actual survey of the land to be granted; having a meriodional line, according to the magnetical needle, by which the survey was made, laid down in it. No notice is taken of the true meridian. The boundary lines of the land granted are marked on earth, (as it is denominated,) by cutting notches on the trees between which the line is run through the woods. These trees being mostly of hard timber, the notches will be discernible for 30 years, or more. By repeated re-surveys these lines are kept up: and, when the cultivation, on both sides, renders it necessary to fell the marked trees, (which can only be done by mutual consent, it being otherwise death by the law,) logwood fences are planted in the lines dividing the properties thus cultivated: and many of these fences have been regularly repaired, and kept up, to the present time. Lands were granted from the Crown soon after the Restoration, in 1660; and every succeeding year the number of patents increased.

The old estates have been often re-surveyed, and plans of them made, and usually annexed to deeds of conveyance, or mortgage, which must be enrolled, within a limited time, in the office of the Secretary of the Island; where, also, all the patents, and diagrams annexed to them, are recorded. In all disputes at law about boundary lines, where the keeping up of the old marked lines on earth has been neglected, surveyors are appointed to make actual re-surveys of all the old marked lines on earth, (preserved in the manner before mentioned,) and to extract from the Secretary of the Island's office, correct copies of all such diagrams annexed to patents, and to deeds of conveyance, or mortgage, of lands in the neighbourhood where the disputed boundary is, as they may think necessary for the investigation thereof. They then compare the lines, and meridians, of these original diagrams with those in their diagrams delineated from their own re-surveys recently made; when it is always expected that the lines, and meridians, of the former will coincide with those of the latter. It is evident that this coincidence could not happen if any variation of the magnetical needle had taken place in the intermediate time elapsed between the making of the first, and of the last, survey. My business being very extensive, I was frequently applied to in disputes at law about boundary lines, and I had, besides, abundance of opportunities, on other surveys, to ascertain this fact satisfactorily. From all which I have discovered that the courses of the lines, and meridians, delineated on the original diagrams annexed to patents, from 1660, downwards to the present time, and of the re-survey diagrams thereof, annexed to deeds, coincide with, and are parallel to, the lines and meridians delineated on the new diagrams from recent surveys made by the magnetical needle, of the same original marked lines on earth, preserved as before described); so that whatever course is laid down for the line on the diagram annexed to the patent, (and let it be supposed, for example, to be north and south, or east and west,) upon setting the compass in the old marked line on earth, and directing the sights north and south, or east and west, according to the magnetical needle, the said marked line on earth, originally run by the magnetical needle 130 or 140 years ago, has been found by me to be exactly in the line, or direction with that of the compass; consequently no alteration of the variation could have taken place during the whole, or any part, of that period of time in Jamaica.

To this it may not be unacceptable to subjoin a short history of the practice of surveying in Jamaica, from the Restoration to the present time, in order to obviate any doubt that might arise, whether there be not a possibility of the quantity of the magnetical variation having been ascertained, and allowed for, in the first diagrams annexed to patents; and whether the variation of 6½ degrees east, which corresponds with the magnetical needle now, might not then, have have agreed with the true meridian.

The variation of the compass was first observed by Columbus, in his first voyage across the Atlantic, in the year 1492; and seemed to threaten that the laws of nature were altered in an unknown ocean. It is evident, however, that Columbus was not able to ascertain the quantity of variation; for if he had ascertained it, the danger he was in would have been diminished, if not entirely removed. His discovery, therefore, must have been, simply, the deflection of the magnetical needle from the true meridian, without knowing the quantity thereof.

From this period down to the year 1700, when Dr. HALLEY published his "Theory of the Variation of the Compass," no observations, ascertaining the quantity of variation, in the West Indies, were, I believe, published. He was the first that made any in South America, and these were chiefly applicable to the coast of Brasil. With his theory was published "A new and correct Chart of the whole World, shewing the "Variations of the Compass, &c. as they were found in 1700, "by Direction of Capt. EDM. HALLEY." By this chart the variation, at Jamaica, appears to have been the same as it is at present. His theory could have been known but to few; nor do any observations, in the West Indies, appear to have been made for many years after its publication. Indeed I know of none till very lately, and these only in a few charts. But, however extensive its publicity might have been, it could have had no influence in directing the surveys, in Jamaica, that preceded it by 30 or 40 years.

The ascertaining of the true meridian, and, consequently, of the magnetical variation from it, requires more scientifical, as well as practical, knowledge, than is often to be met with even at this time; but, 130 or 140 years back, it was entirely confined to a very few individuals. The magnetical needle was then the only guide and rule to go by, both at sea and at land, and, generally, without any reference being had to the true meridian.

Had the first surveyors ascertained the quantity of variation, and allowed for it, in delineating their diagrams that were annexed to the earliest patents in Jamaica, they would have mentioned the same in such diagrams; otherwise it could only tend to mislead, not to direct. The same system of surveying would, and must, by law, have been continued; for, (as was stated above,) the number of grants has been annually increased; and the uninterrupted practice of surveying, which was always daily increasing in proportion to the extending cultivation and settlement of the island, could not admit of any change, without a new law having been made by the legislature for that purpose; and then such a change must have been recorded with the laws of the island, and with those that regulated the conduct of surveyors. No surveyor, nor other person, could have been ignorant of such a change having taken place. Since even the difference of one degree in running a line is very considerable; but that of six would have totally changed all property, deranged all boundaries, thrown woodlands into plantations, and *vice versâ*; and, consequently, would have been so palpable and injurious as to have demanded legislative interference and correction. But no such change has ever happened, nor has the most remote idea of it ever been entertained. On the contrary, the magnetical meridian, in all disputes at law about boundary lines, is and always has been the only criterion by which the surveyors, the court, and the jury, decide.

From the year 1700, when Dr. HALLEY's theory was published, it is very easy to trace down the practice of surveying in Jamaica, as well as up to its commencement. When I arrived in that island, upwards of 25 years since, I became acquainted with the oldest surveyors there, who had practised from 30 to 40 years. They had the original papers, field notes, and diagrams of their predecessors, up to the dates of the first surveys. Many of these original papers, field notes, and diagrams are now in my possession; from which the practice of surveying, taking field notes, and delineating them on diagrams, is clearly shown.

Jamaica was early divided into counties and parishes, the boundary lines whereof were defined by the legislature, and the lines of many marked on earth. In the county of Surrey, the line, dividing the parishes of Portland and St. George, is a north and south line, by law, and was marked on earth according to the magnetical needle. It continues in the same direction. In the county of Cornwall, the dividing line between the parishes of St. James and Trelawney continues a north and south line, on earth, as it was first run by the magnetical needle. This will be evident on the inspection of my maps of Jamaica, lately published. It became necessary, in giving the island its true position on the globe, to ascertain its latitude and longitude; and also the true meridian, with the quantity of the variation of the magnetical meridian from it. But I have applied these meridians differently in the maps of the counties, and in that of the island. In the former, in which the situation on the globe is not given, the magnetical is laid down as the principal meridian; because all surveys of every other description, as well as those of the boundary lines of counties and parishes, are regulated by it; and the true meridian is introduced only to show the variation; but, in the latter, in which its place on the globe is fixed, as to latitude and longitude, the true meridian becomes the principal one; and the magnetical meridian shows the quantity of variation from it, and regulates the surveys, and the relative situation of places, as in the county maps.

When Sir Henry Moore, (who was considered a great surveyor,) was governor of Jamaica, about the year 1760, maps of that island were constructed, under his immediate direction, by Mr. Craskell, the island engineer, and Mr. Simpson, both eminent surveyors. But, in these maps, the magnetical meridian only is represented. Neither the magnetical variation nor the true meridian is mentioned: the island's place on the globe, as to latitude and longitude, is not given. In short, the true meridian has never been noticed, nor the quantity of variation ascertained, nor the variation even mentioned, nor the latitude and longitude, observed by any *surveyor or engineer* in Jamaica, but myself.

Although the discovery of the variation's not varying, in Jamaica, is established on the clearest evidence without the aid of other data, yet it is highly gratifying to find Dr. Halley, as it were, confirming it to the minutest accuracy, as will appear from the recital of the following observations of Mr. Long, in his History of Jamaica.

" The variations of the magnetical needle were observed " by Dr. Halley to be very small, near the equator. I have " seen no account of them for this island, that can be relied " upon; but, if observations should be faithfully made here, " they would probably confirm his opinion. According to " Mountain's chart, constructed in the year 1700, from Dr. " Halley's tables, the variation at Port Royal then was about " 6½ degrees east. But, as in most parts of the world it is " found to be continually either increasing or decreasing, so " we may reasonably conclude, that it may have altered in " both respects very much during this long interval that has " passed since the constructing of the chart."

The magnetical variation, ascertained by me, and laid down in my maps of Jamaica, is 6½ degrees east.

I leave to others, better qualified than I am, to enquire, and to point out, what improvements natural philosophy may derive from this discovery; which I hope may be an acquisition to science.

I am afraid I have been too prolix. But the importance of the subject, and my desire to remove even the shadow of any doubt that might be suggested, will, I trust, be admitted as my apology.

I have the honour to be, &c.

JAMES ROBERTSON.

XIX. *Observations on the Camel's Stomach respecting the Water it contains, and the Reservoirs, in which that Fluid is inclosed; with an Account of some Peculiarities in the Urine.* By Everard Home, *Esq. F. R. S.*

Read June 12, 1806.

The Board of Curators of the Museum belonging to the Royal College of Surgeons, formed of seven Members of the Court of Assistants, have from their first appointment embraced every opportunity of augmenting the Hunterian Collection: and in December, 1805, hearing that a camel in a dying state was to be sold, purchased it with a view of illustrating the anatomy of that animal. They appointed Mr. Long, (their Chairman,) Mr. Cline, Teacher of Anatomy, with Sir William Blizard and myself, the two Professors of Anatomy and Surgery to the College, a Committee for that purpose.

As Professor of Comparative Anatomy I was directed to examine the peculiarities of the stomach, and to make a report on that subject. This report appeared to the Board of Curators to contain some facts, which had not before been ascertained; and it is at their desire that the present communication is made.

The camel, the subject of the following observations, was a female, brought from Arabia; 28 years old, and said to have been 20 years in England, and 12 years in the possession of the person, from whom the Board of Curators purchased it. Its height was seven feet from the ground to the tip of the anterior hump.

In December, 1805, it came under the care of the Committee. At that time it was so weak as hardly to be able to stand. It got up with difficulty, and almost immediately kneeled down again. By being kept warm, and well fed, it recovered so as to be able to walk, but was exceedingly infirm on its feet: and moved with a very slow pace. It drank regularly every second day six gallons of water, and occasionally seven and a half; but refused to drink in the intervening period. It took the water by large mouthfuls, and slowly, till it had done. The quantity of food it daily consumed was one peck of oats, one of chaff, and one-third of a truss of hay. Some of the urine was saved, and sent to Mr. Hatchett for the purpose of having it analyzed: his account of its component parts is contained in a report annexed to this Paper.

In the beginning of February, 1806, it began to shed its coat. Towards the end of March the wind became extremely cold, and the animal suffered so much from it, that it lost its strength, refused its food, and drank only a small quantity of water at a time.

In this state it was thought advisable to put an end to so miserable an existence: and it suggested itself to the Committee that if this was done soon after the animal had drank a quantity of water, the real state of the stomach might be ascertained.

On the 1st of April, by giving the animal hay mixed with a little salt it was induced to drink, at two different times in the course of two hours three gallons of water; not having taken any the three preceding days, or shewn the least disposition to do so. Three hours after this, its head was fixed to a beam, so as to prevent the body from falling to the ground, after it was dead, and in this situation it was pithed by Mr. CLINE, junior, assisted by Mr. BRODIE and Mr. CLIFT. This operation was performed with a narrow double-edged poniard passed in between the skull and first vertebra of the neck; in this way the medulla oblongata was divided, and the animal instantaneously deprived of sensibility. In the common mode of pithing cattle the medulla spinalis only is cut through, and the head remains alive, which renders it the most cruel mode of killing animals that could be invented.*

The animal was kept suspended, that the viscera might remain in their natural state, and in two hours the cavities of the chest, and abdomen were laid open, in the presence of all the Members of the Committee, and Mr. CHANDLER, a Member of the Board of Curators.

The first stomach was the only part of the contents of the abdomen, which appeared in view. The smooth portion of the paunch was on the left side, and on the right towards the chest was a cellular structure, in which it was evident to the feel there was air, but no part of the solid food, with which the general cavity was distended. On the lower posterior part towards the pelvis there was another portion made up of cells, larger and more extensive than that, which was anterior. On pressing on this part a fluctuation of its contents could be distinctly perceived. A trocar with the canula was plunged into the most prominent of the cells, and on withdrawing it there passed through the canula 12oz. of water of a yellow colour, but unmixed with any solid matter. This fact having been ascertained, the first stomach was laid open, on the left side, at a distance from the cellular structure, and the solid contents were all removed. While this was doing some water flowed out of the cells, and some out of the second stomach, but the greater part was retained. That in the second stomach was nearly pure: while the other was muddy, and of a yellow colour, tinged by the contents of the first stomach. On examining the cellular structure no part of the solid food had entered it, nor was there any in the second stomach: those cavities having their orifices so constructed as to prevent the solid food from entering, even when empty.

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* See Dr. DUGARD's experiments, published in the Board of Agriculture's Report for Shropshire, by JOSEPH PLUMLEY, M. A. p. 246.

On measuring the capacities of these different reservoirs in the dead body, they were as follows:

The anterior cells of the first stomach were capable of containing one quart of water, when poured into them. The posterior cells three quarts. One of the largest cells held two ounces and a half, and the second stomach four quarts. This, however, must be considered as much short of what those cavities can contain in the living animal, since there are large muscles covering the bottom of the cellular structure, to force out the water, which must have been contracted immediately after death and by that means had diminished the cavities.

By this examination it was proved, in the most satisfactory manner, that the camel when it drinks, conducts the water in a pure state into the second stomach, that part of it is retained there, and the rest runs over into the cellular structure of the first, acquiring a yellow colour in its course.

This confirms the account given by M. Buffon in his examination of the camel's stomach, as well as that of other travellers, who state that when a camel dies in the desart, they open the stomach, and take out the water, which is contained in it, to quench their thirst.

That the second stomach in the camel contained water, had been generally asserted, but by what means the water was kept separate from the food had never been explained, nor had any other part been discovered, by which the common offices of a second stomach could be performed. On these grounds Mr. Hunter did not give credit to the assertion, but considered the second stomach of the camel to correspond in its use with that of other ruminants, as appears from his observations on this subject stated by Dr. Russell, in his history of Aleppo.

The difference of opinion on this subject led me to examine accurately the structure of the stomachs of the camel, and of those ruminants which have horns, so as to determine, if possible, the peculiar offices belonging to their different cavities.

The most satisfactory mode of communicating the result of this inquiry will be first to describe the different stomachs of the bullock, and then those of the camel, and afterwards to point out the peculiarities, by which this animal is enabled to go a longer time without drink than others, and thereby fitted to live in those sandy desarts of which it is the natural inhabitant. The relative position of the parts is described while the animal was suspended, as that was the state in which the different stomachs could be most accurately examined, without disturbing their contents.

When the first stomach of the bullock is laid open by a longitudinal incision on the left side of the œsophagus, and the solid contents are removed, which in general are very dry, that cavity appears to be made up of two large compartments, separated from each other by two transverse bands of considerable thickness, and the second stomach forms a pouch or lesser compartment, on the anterior part of it, rather to the right of the œsophagus, so that the first and second stomach are both included in one general cavity, and lined with a cuticle.

The œsophagus appears to open into the first stomach, but on each side of its termination there is a muscular ridge, projecting from the coats of the first stomach, so as to form a channel into the second stomach.

These muscular bands however do not terminate there, but are continued on to the orifice of the third stomach, in which they are lost.

When these parts are examined, it is evident that the food can pass readily from the œsophagus, either into the general cavity of the first stomach or into the second, which last is peculiarly fitted by its situation, and the muscular power of its coats both to throw up its contents into the mouth, and to receive a supply from the general cavity of the first stomach at the will of the animal.

It was ascertained by examining the stomachs of several bullocks immediately after they were knocked down, that the second stomach contained the same kind of food as the first, only more moist; it must therefore be considered as a shelf from which the food may be regurgitated along the canal, continued from the œsophagus. There is indeed no other mode by which this can be effected, since it is hardly possible for the animal to separate small portions from the suface of the mass of dry food in the first stomach, and force it up into the mouth.

It was also found that when the bullock had been four days without water before it was killed, which is by no means uncommon, the food in the second stomach was very moist, while that in the first was very dry; and when the animal was killed 24 hours after having had water, by making an opening into the second stomach before the other parts were disturbed, nearly a quart of water ran out of it, little mixed with solid food. The man of the slaughter-house also mentioned, upon being asked where the water was met with, that it was always found in the honeycomb'd bag. The water must be received into this stomach while the animal is drinking, for it could not afterwards be conveyed there from the first, as it would naturally drain through the food and remain at the bottom of its cavity.

The second stomach, by receiving the water, is enabled to have its contents always in a proper state of moisture, to admit of its being readily thrown up into the mouth for rumination, which appears to be the true office of this stomach, and not to receive the food after that process has been gone through, as is very generally believed, for in that case the cud would be mixed and lost in the general contents of this cavity, instead of being forwarded to the true digesting stomach.

When the food is swallowed the second time, the orifice of the third stomach is brought forwards by the muscular bands, which terminate in it, so as to oppose the end of the œsophagus, and receive the morsel, without the smallest risk of its dropping into the second stomach.

The third stomach of the bullock is a cavity, in the form of a crescent, containing 24 septa, 7 inches broad, about 23, 4 inches broad, and about 48 of 1¼ inch, at their broadest part. These are ranged in the following order. One broad one, with one of the narrowest next it; then a narrow one, with one of the narrowest next it; then a broad one, and so on. The septa are very thin membranes, covered with a cuticle, and have their origin in the orifice leading from the œsophagus, so that whatever passes into the cavity must fall between these septa, and describe three-fourths of a circle, before it can arrive at the orifice leading to the true stomach, which is so near the other, that the distance between them does not exceed three inches: and therefore the direct line from the termination of the œsophagus to the orifice of the fourth stomach is only of that length. While the young calf is fed on milk, that liquor, which does not require to be ruminated, is conveyed directly to the fourth stomach, not passing between the plicæ of the third; and afterwards the solid food is directed into that cavity, by the plicæ being separated from each other.

The food found in the third stomach is of the consistence of thick paste: and is met with in the form of flattened pellets, distributed between the different septa.

When this cavity is opened, it emits an odour of a very unpleasant kind, arising from the process, which the food undergoes in it.

The third stomach opens into the fourth by a projecting valvular orifice, and the cuticular lining terminates exactly on the edge of this valve, covering only that half of it, which belongs to the third.

The fourth or true digesting stomach is about 2 feet 9 inches long: its internal membrane has 18 plicæ beginning at its orifice, (9 on each side,) 4 inches broad. They are continued down for about 22 inches, increasing to a great degree its internal surface: beyond these the internal membrane is thrown into rugæ, which follow a very serpentine direction, and close to the pylorus there is a glandular projection, one end of which is opposed to the orifice, and closes it up, when in a collapsed state.

These appearances will be better explained by the drawings (Plates XV. and XVI.) than by verbal description.

The camel's stomach anteriorly forms one large bag, but when laid open is found to be divided into two compartments on its posterior part, by a strong ridge which passes down from the right side of the orifice of the œsophagus in a longitudinal direction. This ridge forms one side of a groove that leads to the orifice of the second stomach, and is continued on beyond that part, becoming one boundary to the cellular structure met with in that situation. From this ridge eight strong muscular bands go off at right angles, and afterwards form curved lines till they are insensibly lost in the coats of the stomach. These are at equal distances from each other, and being intersected in a regular way by transverse muscular septa, form the cells. This cellular structure is in the left compartment of the stomach, and there is another of a more superficial kind on the right, placed in exactly the opposite direction, made up of 21 smaller rows of cells, but entirely unconnected with the great ridge. The appearance these parts put on, and their relative situation, will be distinctly seen in the annexed drawing (Plate XVII.). On the left side of the termination of the œsophagus a broad muscular band has its origin, from the coats of the first stomach, and passes down in the form of a fold parallel to the great ridge, till it enters the orifice of the second stomach, which gives it another direction. It is continued along the upper edge of that cavity, and terminates within the orifice of a small bag, which may be termed the third stomach.

This band on one side, and the great ridge on the other, form a canal, which leads from the œsophagus down to the cellular structure in the lower part of the first stomach.

The orifice of the second stomach, when this muscle is not in action, is nearly shut, and at right angles to the side of the first. Its cavity is a pendulous bag, in which there are 12 rows of cells, formed by as many strong muscular bands passing in a transverse direction, and intersected by weaker muscular bands so as to form the orifices of the cells. Above these cells, between them and the muscle, which passes along the upper part of this stomach, is a smooth surface extending from the orifice of this stomach to the termination in the third.

From this account, it is evident that the second stomach neither receives the solid food in the first instance, as in the bullock, nor does it afterwards pass into its cavity or cellular structure.

The food first passes into the general cavity of the first stomach, and that portion of it, which lies in the recess immediately below the entrance of the œsophagus under which the cells are situated is kept moist, and is readily returned into the mouth, along the groove formed for that purpose, by the action of the strong muscle, which surrounds this part of the stomach, so that the cellular portion of the first stomach in the camel performs the same office as the second in the ruminants with horns. While the camel is drinking, the action of the muscular band opens the orifice of the second stomach, at the same time that it directs the water into it: and when the cells of that cavity are full, the rest runs off into the cellular structure of the first stomach immediately below, and afterwards into the general cavity; it would appear that camels, when accustomed to go journeys in which they are kept for an unusual number of days without water, acquire the power of dilating the cells, so as to make them contain a more than ordinary quantity as a supply for their journey, at least such is the account given by those who have been in Egypt. When the cud has been chewed it has to pass along the upper part of the second stomach before it can reach the third. How this is effected without its falling into the cellular portion, could not from any inspection of dried specimens be ascertained; and it was in this state only that Mr. HUNTER saw the internal structure of the camel's stomach; but when the recent stomach is accurately examined, the mode in which this is managed becomes very obvious. At the time that the cud is to pass from the mouth the muscular band contracts with so much force, that it not only opens the orifice of the second stomach, but acting on the mouth of the third, brings it forwards into the second, by which means the muscular ridges that separate the rows of cells are brought close together, so as to exclude these cavities from the canal through which the cud passes.

It is this beautiful and very curious mechanism which forms the peculiar character of the stomach of the camel, dromedary, and lama, fitting them to live in the sandy deserts where the supplies of water are so very precarious.

The first and second stomachs of the camel, as well as those of the bullock, are lined with a cuticle.

The third stomach of the camel is so small, and so very unlike that of other ruminants, that were it not for the distinctness of its orifices it might be overlooked. It is nearly spherical, 4 inches in diameter, is not like the third of the bullock lined with a cuticle, nor has it any septa projecting into it. The cuticle continued from the second stomach terminates immediately within its orifice, and its surface has a faint appearance of honeycombed structure; but this is so slight as to require a close inspection to ascertain it.

This cavity can answer no other purpose in the economy of the animal, than retarding the progress of the food, and making it pass by small portions into the fourth stomach, so that the process, whatever it is which the food undergoes in the third stomach of other ruminants, would appear to be wanting in the camel, and consequently not required.

The fourth stomach lies to the right of the first, and has for a great part of its length the appearance of an intestine; it then contracts partially, and the lower portion has a near resemblance in its shape to the human stomach. Its whole length is 4 feet 4 inches; when laid open, the internal membrane of the upper portion is thrown into longitudinal narrow folds, which are continued for about three feet of its length; these terminate in a welted appearance; the rugæ are large, as in the bullock, but not so prominent, nor so serpentine in their course, and for the last nine inches the membrane has a villous appearance, as in the human stomach. Close to the pylorus there is a glandular substance of a conical form, which projects into the cavity; the blunt end of it resting upon the orifice of the pylorus. This is similar to what is met with in the bullock, but still more conspicuous.

The fourth stomach of the camel corresponds with that of the bullock in all the general characters, and resembles it in most particulars. It exceeds it in length, but the plicæ are so much smaller, that the extent of the internal surface must be very nearly the same in both. It differs from it in having a contraction in a transverse direction immediately below the termination of the plicated part, which has led both DAUBENTON and CUVIER to consider these two portions as separate cavities. I should have been induced to adopt this opinion, were it not for the circumstance of their internal structure being the same as that of the bullock, which must be admitted to be only one cavity, and as the uses of these corresponding structures must be similar, the analogy between the two is better kept up by considering it in both animals as one cavity, only remarking the contraction in that of the camel as a peculiarity belonging to ruminants without horns.

From the comparative view which has been taken of the stomachs of the bullock and camel, it appears that in the bullock there are three stomachs formed for the preparation of the food, and one for its digestion. In the camel there is one stomach fitted to answer the purposes of two of the bullock, a second employed as a reservoir for water, having nothing to do with the preparation of the food; a third so small and simple in its structure that it is not easy to ascertain its particular office. It cannot be compared to any of the preparatory stomachs of the bullock, as all of them have a cuticular lining, which this has not; we must therefore consider it as a cavity peculiar to ruminants without horns; and a fourth, or true digesting stomach.

It is stated by authors that hares, rabbits, and even some men ruminate; their doing so is not material to the present inquiry, since their stomachs are not of that kind which makes rumination a necessary part of the process of digestion; and as far as I can learn from some persons who feed rabbits and fatten them with meal, although they have watched their rabbits with attention they never saw them bring up the food into the mouth. It may therefore be only occasional when they eat particular kinds of vegetables. They have indeed a mode of working their lips when sitting quiet, which may have been mistaken for rumination. When it takes place in men it must be considered as a disease.

From the facts which have been stated, the following gradation of ruminating stomachs is established.

The ruminants with horns, as the bullock, sheep, &c. have two preparatory stomachs for the food previous to rumination, and one for the food to be received in after rumination before it is digested.

The ruminants without horns, as the camel, dromedary, and lama, have one preparatory stomach before rumination, and, properly speaking, none in which the cud can be afterwards retained before it goes into the digesting stomach.

Those animals who eat the same kind of food with the ruminants yet do not ruminate, as the horse and ass, have only one stomach, but a portion of it is lined with cuticle, in which situation the food is first deposited, and by remaining there some time is rendered afterwards more easily digestible when received into the other, or digesting portion.

In comparing the teeth of those animals that ruminate, with those of the horse and ass, which live on nearly the same kind of food, the following peculiarities are met with.

The ruminants with horns have molares in both jaws, and incisores only in the lower jaw.

The ruminants without horns have, in addition to these, what may be called fighting teeth, or a substitute for horns. These are tusks in both jaws, intermediate teeth between the molares and tusks, and in the upper jaw two small teeth anterior to the tusks; none of which can be of any use in eating.

The camelo-pardalis forms an intermediate link in these respects. It has short horns, and has no tusks.

The molares in both these genera of ruminants are open in the structure of their crown, which is not horizontal but oblique, the outer edge in the upper jaw and the inner in the lower jaw being the most prominent, so as to adapt them to each other. The lower jaw has less width than the upper, so that the lower molares fall considerably within the upper; when the animal eats it can only masticate with one side of the mouth at a time, by bringing the lower jaw to that side, so as to make the teeth of both jaws oppose each other; the teeth of that side are applied to the food three or four times, and then those of the opposite side.

This mode of mastication appears to be peculiar to the ruminants, and is certainly very different, and much more imperfect than the mastication of the horse, whose molares are very compact in the texture of their crowns, and are opposed directly to each other by horizontal planes.

Letter from Charles Hatchett, *Esq. concerning some Peculiarities in the Urine of the Camel.*

DEAR SIR, April 30, 1806.

Being a short time absent from my house, and not having at hand any apparatus to examine the camel's urine, which you lately sent to me, I delivered it to my friend, Mr. W. Brande, of Arlington-street, who has on several occasions much distinguished himself in chemical science, and I now have the pleasure of transmitting an account of the results of his comparative experiments on the urine of the camel and the cow, which, I think, appear to be highly deserving of attention.

The presence of uric acid in the former, and that of phosphat of lime in both, are new facts, which reflect additional light on the composition of the urine of graminivorous animals.

Mr. Brande first states his experiments on the camel's urine as follows:

"I divided it into two equal portions, taking half for distillation, which was performed at a very low temperature.

"When somewhat more than three-fourths had passed over, the residuum in the retort became thick, assuming a deep brown colour, and having a peculiar fetid odour. I now stopped the distillation, and affused alcohol, with a view of ascertaining whether it contained urea. This I obtained in a considerable proportion. It had the same appearance and properties as that which is afforded by human urine. What remained after the separation of the urea, consisted chiefly, as far as I could ascertain, of muriat of potash, with a little muriat of ammonia, phosphat of lime, and probably urat of potash.

"I may here remark that no benzoic acid was separated towards the latter part of the distillation, nor could I obtain any from the residuum.

"The remaining portion of the urine was examined by the following tests:

"Nitrat of silver occasioned a very copious precipitate, which became speedily black on exposure to light.

"Muriat of barytes indicated the presence of a minute portion of sulphuric acid.

"Ammonia threw down a little phosphat of lime. When muriatic acid was poured into the urine, an effervescence was produced by the emission of carbonic acid gas.

"A portion of the urine, which had been exposed to the air for some days, deposited a sediment, which when treated with nitric acid, and evaporated, assumed a red colour, and thereby shewed the presence of uric acid.

"From the results of these experiments, and of some others, which I do not think it necessary to mention, I have drawn the following conclusions relative to the component parts of camel's urine; but as the quantity, upon which I operated was small, they must only be regarded as an approximation to the truth.

Water - - -	75
Phosphat of lime -	6
Muriat of ammonia -	
Sulphat of potash - -	
Urat of potash -	
Carbonat of potash -	
Muriat of potash - - -	8
Urea - - - - -	6
	95."

Mr. Brande next proceeds to give an account of his examination of cow's urine.

"As I had sent me a large supply of cow's urine, I have been enabled to vary my experiments on it, in such a manner, that I hope to have drawn tolerably accurate conclusions with respect to its composition.

"The analysis was conducted nearly as follows:

"1. I put four ounces into a glass retort, to which a proper apparatus was adapted for collecting its gaseous as well as fluid parts. The distillation was performed in a sand-bath.

"I obtained carbonic acid and water, shewing some signs of ammonia; possessing however a peculiar flavour. There remained in the retort a brown mass, which was chiefly composed of muriat of potash, and of ammonia; sulphat of potash, phosphat of lime, and urea.

"The carbonic acid must in part have been produced from a decomposition of a portion of urea: and hence the brown colour of the residuum.

"2. Four ounces of the urine were evaporated to half the quantity. Muriatic acid was added, and a precipitate was formed, from which I obtained a small portion of benzoic acid.

"It is somewhat remarkable that no traces of this substance should have been discovered in the residuum left after distillation; nor could I by any means observe its presence before heat had been employed.

"I mention this circumstance, as I think it coincides with your opinion respecting the formation of this acid; and that in this case it is not an educt, but a product.

"Still I do not see why by a similar process I could obtain none from the urine of the camel.

"3. The cow's urine was then examined by the following reagents.

"Nitrate of silver caused an abundant precipitation of muriate of silver.

"Barytes was thrown down in the form of sulphat and carbonat: the latter in the smallest proportion.

"Ammonia indicated the presence of phosphat of lime.

"Carbonic acid gas was extricated by muriatic acid.

"The results, which I had obtained from the analysis of camel's urine, induced me to imagine that uric acid might possibly exist in the urine of other graminivorous animals; and indeed it was a natural conclusion: but I find that it is not the case, for in the present experiments I have been unable to detect even the least trace of that substance.

"The following estimation of the relative proportions of the substances present is, I think, as correct as the nature of the subject will allow.

" 100 parts contain

Water - - - -	65
Phosphat of lime - - -	3
Muriat of lime - - -	15
——— ammonia - -	
Sulphat of potash - - -	6
Carbonat of potash - - -	4
——— ammonia - -	
Urea - - -	4
	97.

" The loss may be attributed to animal matter, probably albumen and gelatine.

" I have for obvious reasons omitted the benzoic acid.

" The principal and only essential difference between the urine of the camel, and that of the cow, is that the former contains uric acid. They both appear to be destitute of soda.

" It will also appear that in the present instance the latter contains a larger proportion of saline matter, but this can only be regarded as a casualty, when we consider the variation, to which the relative proportion of water to the salts of urine is liable, according to the circumstances under which the secretion takes place."

From Mr. BRANDE's experiments on the urine of the camel, it appears that (exclusive of water) the principal ingredients are muriat of potash, and urea; and as ammonia is present only in a very small proportion, which is even less than in the urine of the cow, we may conclude that the various accounts, which state the urine of the camel to have much contributed to the production of muriat of ammonia, or sal ammoniac, are without foundation.

It is remarkable that uric acid should be found in the camel's urine, and I believe it is the first instance on record, as far as relates to the urine of graminivorous animals.

Mr. **Brande**'s experiments also show that phosphat of lime is present in the urine of these animals, which is in opposition to the hitherto received opinion.

Fourcroy and Dr. **Thomson** have quoted the analyses of camel's and cow's urine made by **Rouelle**, and it may not be improper to compare them with those of Mr. **Brande**.

Component Parts of Camel's Urine.

Brande.		**Rouelle.***
Water - - -	75	
Phosphat of lime -	6	
Muriat of ammonia -		Carbonat of potash
Sulphat of Potash -		Sulphat of potash
Urat of potash -		
Carbonat of potash -		Muriat of potash
Urea - - -	6	Urea.
Muriat of potash -	8	
	95	

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* **Thomson**'s System of Chemistry, 2d edit. Vol. IV. p. 655.

Component Parts of Cow's Urine.

Brande.		Rouelle.
Water - - -	65	
Phosphat of lime -	3	Carbonat of potash
Muriat of potash - ——— ammonia -	15	Sulphat of potash
Sulphat of potash -	6	Muriat of potash
Carbonat of potash - ——— ammonia -	4	Urea
Urea - - -	4	Benzoic acid.
	97	

From this comparison, we see that Mr. Brande and M. Rouelle agree in stating that potash is the only fixed alkali present in both cases.

The urine of the rabbit, according to Vauquelin, is composed as follows.

Carbonat of lime
——— magnesia
——— potash
Sulphat of potash
——— lime
Muriat of potash
Urea
Gelatine
Sulphur.

The same chemist found that the urine of the guinea-pig deposited carbonat of lime: that it changed the colour of syrup of violets to green; and that it contained carbonat, and muriat of potash; but not any phosphat, nor uric acid.

From all these it therefore appears, that soda and its combinations do not form any part of the urine of the camel, cow, guinea-pig, and rabbit; unless we may be permitted to believe that the composition of the urine of animals in general, is various at different periods, not only in the proportions of the ingredients, but also in the quality.

Should however the contrary of this be the case, we may assert that the urine of the horse is peculiarly distinguished from that of the above mentioned animals, by the presence, and abundance of soda, as the following analysis made by FOURCROY and VAUQUELIN will demonstrate.

*Component Parts of the Urine of the Horse.**

Carbonat of lime	0011
——— soda	0009
Benzoat of soda	0024
Muriat of potash	0009
Urea	0007
Water and mucilage	0940
	1000.

Now unless the urine of animals is very differently composed at different periods, there is in this instance a marked chemical character between the urine of the horse, and that of the above-mentioned graminivorous animals: and if so, perhaps the same may prevail respecting those other animals, which are the most nearly allied to the horse.

This certainly merits investigation; but it can only be accomplished by a number of comparative experiments, and analyses made on the urine of the same and of different animals at various times, and under different circumstances.

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* THOMSON, Vol. IV. p. 655.

I am, &c.

CHARLES HATCHETT.

P. S. Since the foregoing letter was written, Mr. W. BRANDE has examined the urine of the horse and ass; the result is as follows:

"The urine of the horse is turbid, and of a mucilaginous consistence; it changes the colour of vegetable blues to green, and when exposed to the air it becomes covered with a thin pellicle of carbonat of lime.

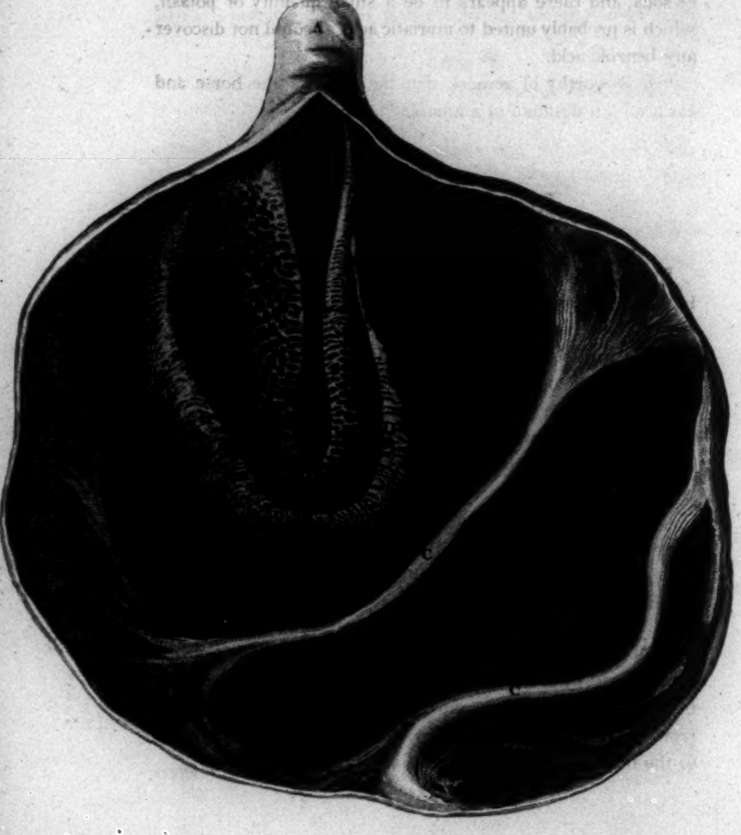
"When evaporated to the consistence of thick honey, it yields to alcohol a small portion of urea. The salts which it contains are as follows:

Carbonat of lime
———— soda
Sulphat of soda
Muriat of soda
Benzoat of soda
Phosphat of lime.

"These amounted in the present instance to about one-eighth of the urine. I could discover no trace either of potash or ammonia.

The urine of the ass is somewhat mucilaginous: but at the same time transparent. Like that of the horse it changes vegetable blues to green; but it deposits no carbonat of lime.

"It differs in its composition from that of the horse, by containing a much greater relative proportion of phosphat of



lift del. *Basire sc.*

lime and urea: it contains also carbonat, sulphat, and muriat of soda, and there appears to be a small quantity of potash, which is probably united to muriatic acid. I could not discover any benzoic acid.

"It is worthy of remark that the urine of the horse and ass are both destitute of ammonia."

EXPLANATION OF THE PLATES.

Plate XV.

Represents a longitudinal section of the first stomach of the bullock, showing its cavity, which is made up of two compartments, separated from each other by two strong transverse ridges, composed of a mixture of ligamentous and muscular fibres: also the opening into the second stomach, and a portion of its cavity: the orifice leading into the third stomach, and the canal through which the food is thrown up from the second stomach into the mouth, and afterwards conveyed into the third stomach.

a, The œsophagus terminating in the first stomach.

bbbb, The cavity of the first stomach.

cc, The two ridges dividing it into two compartments.

dd, The mouth of the second stomach.

e, The orifice leading to the third stomach.

ff, Two muscular bands, which have their origin from the coats of the first stomach and terminate in the orifice of the third, forming a canal, along which the food is conveyed from the second stomach, to the mouth, and from the mouth to the third stomach.

Plate XVI.

Represents a posterior view of the first and second stomachs of the bullock unopened, and an internal view of the third and fourth stomachs, in their natural relative situation to the others.

a, The œsophagus.

bb, The coats of the first stomach, in a distended state.

c, The coats of the second stomach.

d, The orifice leading into the third stomach.

eee, The plicæ of three different breadths, which are contained in the third stomach.

f, The valvular termination of the third stomach in the fourth.

ggg, The longitudinal plicæ of the fourth stomach.

h, The rugæ of the fourth stomach, near the pylorus.

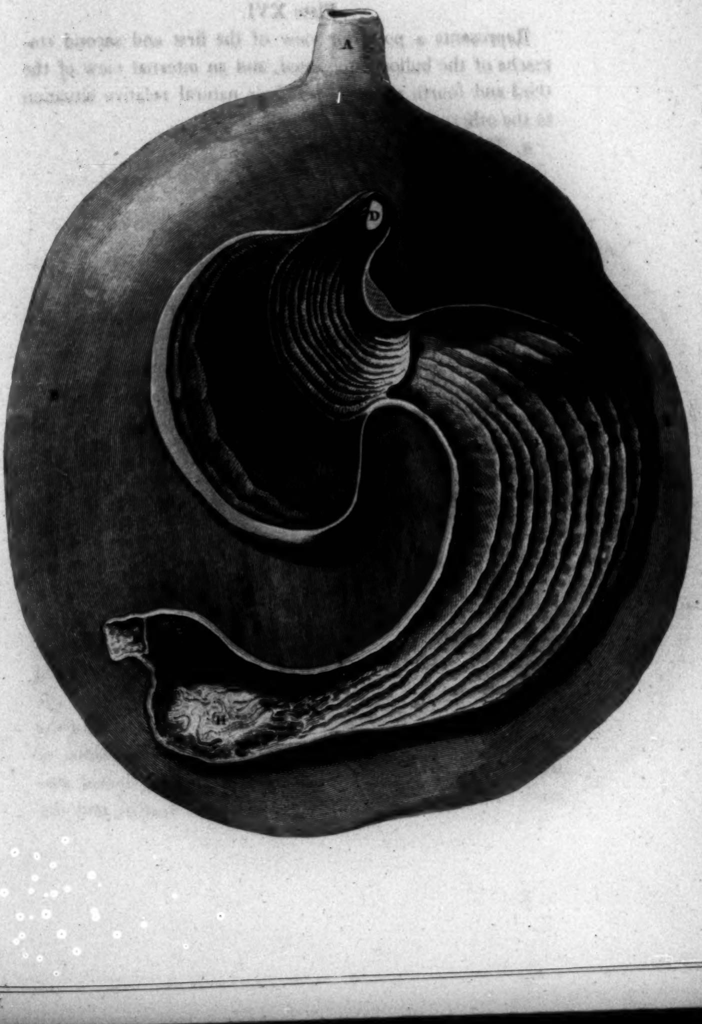
i, The glandular projection opposed to the orifice of the pylorus.

k, The pylorus, or termination of the fourth stomach.

Plate XVII.

Represents an internal view of the first stomach of the camel, exposed in the same manner as that of the bullock, in Pate XV.

In this stomach there are two compartments, separated from each other by a longitudinal ridge, which is composed of strong muscular fibres, and the orifice leading into the second stomach is nearly at right angles to the cavity of the first; there is a strong muscle passing from the orifice of the first stomach through the upper part of the second stomach to the third, where it terminates; this muscle, and the



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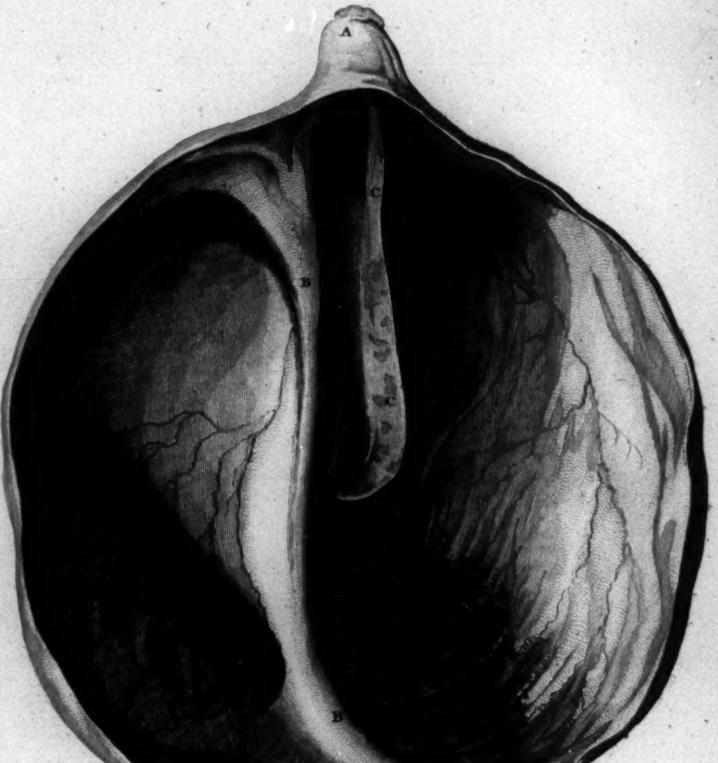

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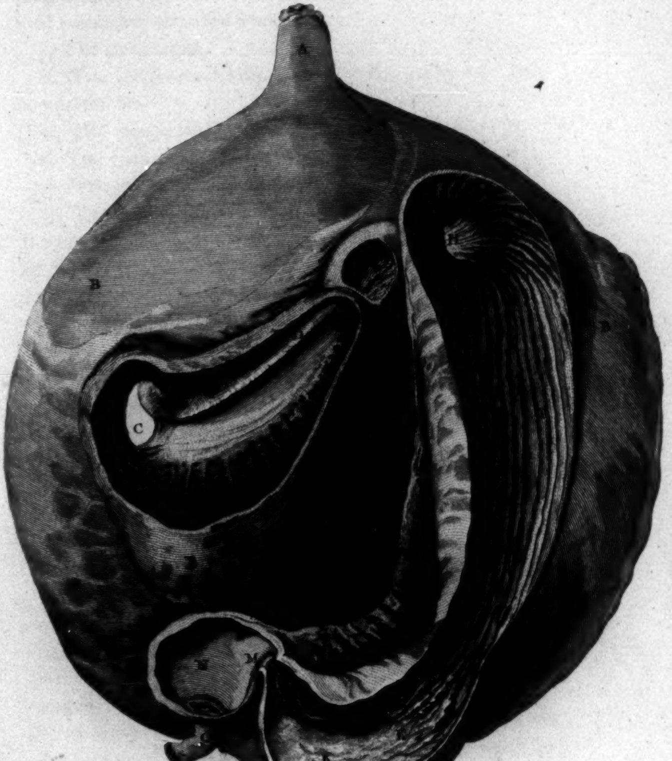

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longitudinal ridge form a canal along which the ruminated food passes into the third stomach.

a, The œsophagus.

bb, The longitudinal ridge, dividing the cavity into two compartments.

cc, The muscle which passes to the third stomach.

d, The opening into the second stomach.

ee, The muscular cells on the right side of the cavity.

ff, The larger cells on the left side, which serve to moisten the food lying over them, and make it of a fit consistence to be regurgitated into the mouth along the canal formed by the longitudinal ridge and the muscle going to the third stomach.

gg. A broad muscular band separating the cellular structure into two portions.

Plate XVIII.

Represents a posterior view of the first stomach of the camel unopened, and an internal view of the second, third, and fourth stomachs, in their relative situation to the first, similar to the view given of the stomachs of the bullock, in Plate XVI.

a, The œsophagus.

bb, The coats of the first stomach, in a distended state.

c, The communication between the first and second stomachs.

dd, The muscle running along its upper part to terminate in the orifice of the third stomach. This muscle when it acts with its greatest force brings forward the orifice of the third stomach nearly close to that of the second, and by so doing shuts up the rows of cells in the lower part of the cavity so that no part of the solid food can pass into them.

ee, The rows of cells which form a reservoir for the water.

f, The opening leading into the third stomach.

g, The cavity of the third stomach.

h, The orifice of the fourth stomach.

ii, The longitudinal plicæ of the fourth stomach.

kk, The rugous structure of the lower part of the fourth stomach.

l, The glandular projection opposed to the orifice of the pylorus.

m, The pylorus.

n, A dilatation or membranous cavity between the pylorus and duodenum.

o, The duodenum.

Plate XIX.

This plate is intended to show the directions of the muscular fibres which run upon the orifices and sides of the cells in the first and second stomachs of the camel.

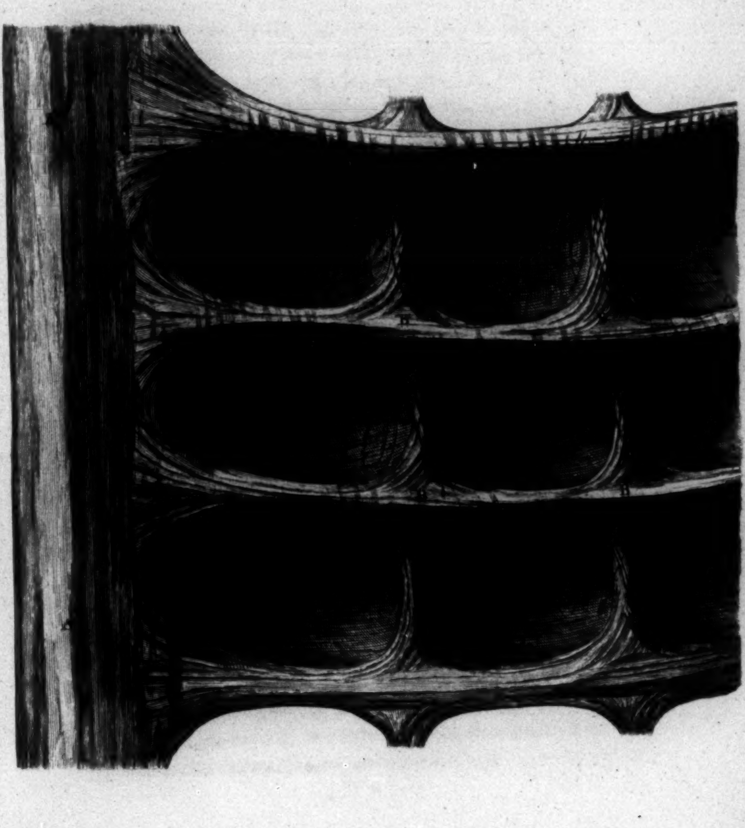
It represents six of the cells in the lower part of the left side of the first stomach, with a portion of the longitudinal ridge by which they are bounded. These particular cells were chosen in preference to those of the second stomach, as they were the largest, and the muscular fibres were most distinctly seen; the same structure is met with in the cells of the second stomach.

aa, The longitudinal ridge, to show its muscular structure, and the mode in which the fibres go off to furnish the orifices of the cells.

bbbbb, The course of the fibres going from cell to cell to close their orifices.

cc, The muscular fibres by which the cells are enabled to throw out their contents.

Philos. Trans. MDCCCVI. Plate XIX. p. 384.



W. Clift del.

Basire sc.

XX. *Observations on the Variation, and on the Dip of the magnetic Needle, made at the Apartments of the Royal Society, between the Years 1786 and 1805 inclusive. By Mr.* George Gilpin. *Communicated by* Henry Cavendish, *Esq. F. R. S.*

Read June 19, 1806.

Of the Variation Compass.

The variation compass used in making the following observations is the same instrument used in former observations of the variation, and published by the Society in several volumes of their Transactions: and as a particular and accurate description of its construction was given by Henry Cavendish, Esq. F.R.S. in the LXVIth volume, it will not be necessary to say any thing here on that subject. But these observations being the first that have been communicated since the compass was put up in the Society's apartments in Somerset Place, it may not be amiss to point out its situation in the house at the time of observation, and the method pursued to attain such allowances as were proper to be made in deducing the results here given.

1. The compass in the house, at the time of observation, was placed in the middle window, on the south side of the Society's meeting-room, upon a strong mahogany board 1½ inch thick. Against the opposite building the dial-plate of a watch is fixed, making an angle with the true meridian of 31° 8',8 to the eastward, as a mark to which the telescope of

the compass was adjusted. To obtain the angle that this mark made with the true meridian, I fixed a transit-instrument on the mahogany board above mentioned, precisely in the same place where the compass had been placed, and having adjusted its telescope to the said mark, the transits of the sun and stars over a vertical circle passing through the zenith and this mark, were observed; and the angle contained between the said mark and the true meridian, was found by computation to be 31° 8',8 as above.

2. For the purpose of ascertaining what error there might be, from a want of parallelism between the line joining the indices and the magnetism of the needle, and thereby to determine whether in the usual method of observing, the indices shew the true angle which the direction of magnetism makes with the first division or zero, a great many observations were made on both ends of the needle, and with both sides of the needle uppermost, (the cap of the needle being made to fit on readily on either face for this purpose,) *viz.* north end and south end in its upright position, and north end and south end with the needle inverted, and the mean of the four giving the angle greater by 2', than that shewn by the north end in the upright position of the needle, (which was the end always used in these observations,) two minutes have been added to all the observations read from the instrument, as the correction for this error to angles on the east side of zero, and subtracted from angles on the west side, to obtain the true angle; which error to angles on the west side, however, only occurred, when the instrument was taken out of doors to determine the effect of the iron work of the building.

3. The variation compass being placed in the house for observation, could not be supposed to be entirely out of the influence of iron; I was therefore desirous to ascertain how far that influence might extend; for the determination of which, the following method was adopted.

Having caused to be sunk into the earth to some depth a strong post, in the wood yard of Somerset House, at a considerable distance from the influence of any iron, on which the compass might be placed, and from which station, there was a convenient mark at a proper distance to which its telescope could be adjusted; I took the compass there at those times of the day when the needle was stationary, *viz.* morning and afternoon: before the compass was carried out of doors, observations were made in the room; then it was taken out of doors to the above mentioned station for observation there; and the observations were again repeated after the compass had been restored to its situation in the room; so that had any alteration taken place in the interval, such alteration would have been detected; but during the whole series, no material difference occurred between the observations made in the house before, and after those taken in the yard.

The observations therefore made in the yard, compared with those taken in the house, both before and after those taken out of it, formed the comparison for obtaining the error, or the effect of the iron work of the room on the needle in the house, and there is reason to believe that considerable accuracy has been obtained. They are as follow.

By a mean of 20 sets, or 200 observations taken with the compass in the yard, compared with twice that number taken in the house, before and after those taken in the yard, the variation observed in the house was found to be greater than that observed in the yard by 5′,4. The mean of nine sets of observations taken in the morning giving for the error 5′,5. And the mean of eleven taken in the afternoon giving for the error 5′,3. The variation in those tables have therefore been lessened by the above mentioned quantity 5′,4, as the error for the effect of the iron work of the room on the needle in the house.

I must not omit to mention that of these 20 sets of observations mentioned above, nine only were made with the compass in the same situation, and eleven in that of a different one; for, after nine sets had been taken, a pile of boards was put up between the compass and the mark to which it had been adjusted, which made it necessary to remove the post on which the compass had been placed, a few feet to the westward of its former situation, to clear it from the said pile of boards; and eleven sets of observations were made from this new station, with the compass adjusted to the same mark it had been adjusted to before, and the angles that this mark made with the true meridian from each of these stations, were ascertained by placing a transit-instrument precisely where the compass had been placed, and observing transits of the sun and stars, in the same manner as has been described in finding the angle of the mark that the compass was adjusted to in the house. And it is conceived that this accidental circumstance adds some weight to the accuracy with which these operations were performed, as the error from the two results of nine, and eleven, does not differ so much as 0′5 from each other.

Dipping Needle.

The dipping needle with which the observations in this communication were made, being the same instrument used in former observations of the dip, and it having also been described by Mr. CAVENDISH in the Paper before alluded to, it will not be necessary to say any thing of its construction here. Its situation in the house was in the eastern window in the meeting-room, next the door.

As the observations made with the dipping needle were not affected by any other source of error than that of the iron work of the room, in order to ascertain the quantity of error, the instrument was taken out of doors at two different times, after an interval of ten years, differently situated each time, and the observations made at both these times out of doors, compared with the observations made in the room, giving for the error 20′ more than the dip was found to be in the room, and both agreeing to one minute; that quantity has been added to all the observations made with the dipping needle in the room for its error, as affected by the iron work of the room.

Although a valuable Paper on the diurnal variation of the horizontal magnetic needle, by the late Mr. JOHN CANTON, F. R. S. was published in the first part of the LIst volume of the Phil. Trans. for the year 1759, containing a great number of observations made at different and irregular times of the day throughout the year; yet, it appeared to me, that if the variation were to be observed at short but stated intervals of the day for one year, the results would perhaps not only prove more satisfactory in determining the times of the needle becoming stationary, but would show its progressive and regressive motions better, than if observed at irregular intervals. To effect which, I imposed this laborious task upon myself for the space of sixteen months.

The observations contained in Table I. in sixteen pages, *viz.* from September, 1786, to December, 1787, both inclusive, are the results, made at many but stated times of the day, and so disposed, that the progress, or regress, of the variation, may be readily seen by mere inspection.

Table II. contains the mean monthly variation for the above mentioned times of the day contained in Table I.

Table III. contains, besides the mean monthly true variation, and mean monthly diurnal alteration of variation, for the sixteen above mentioned months, the mean monthly true variation, and diurnal alteration of variation for many months in the year, between the years 1786 and 1805 inclusive.

The numbers put down in Table I. are each of them a mean of five observations, and often more.

Those in Table II. depend on Table I.

As the observations from which the true variation has been given in Table III. between the years 1788 and 1805 were too numerous to be all inserted, it has been thought sufficient to give the mean monthly true variation, and mean monthly diurnal alteration of variation only; and they were determined from a mean of the observations made at those times of the day when the variation was considered least, and greatest; which variations for each month, may generally be considered as a mean of 600 observations.

From the observations made by the late Dr. HEBERDEN and others, about the year 1775, the variation was found to increase annually nearly 10′, since that time to the present, its rate of increase has been considered as gradually diminishing,* and for the last three or four years the alteration has been so very small as to make it somewhat doubtful whether it may not be considered stationary, but I would not from so short a period conclude that it really is so.

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* An exception to the progressive increase appears between the years 1790 and 1791, as the observations between these two years make it to decrease 2 or 3′, and subsequent observations to increase again; to what this should be attributed, I am at a loss to account, unless it arose from the alteration which took place in the iron work of the room in December, 1790; four strong iron braces having been applied to the girders in the floor of the great room of the Royal Academy, (which is over the Society's meeting-room,) in consequence of a cracking noise made from the great pressure of a number of persons in the room during the time that Sir JOSHUA REYNOLDS was delivering a lecture; these braces were applied two on each side of, and equidistant from, the compass, the nearest, about 18 feet from it. It may be proper to mention, however, that having been favoured with the variation observed both by Mr. CAVENDISH and Dr. HEBERDEN, in the above mentioned years the alteration of the variation was by the former nearly the same as in my own, but by those of the latter greater in both cases.

An alteration took place between the observations made with the dipping needle in the same years. All the iron braces were on the north west side of the needle, and the nearest about 18 feet from it.

The allowances made to the observations of the variation, and also of the dip, for the effect of the iron work of the room, were both ascertained after the above mentioned alteration in the iron work took place, but they have, notwithstanding, been applied to the observations made before as well as since that time.

From the observations of sixteen months, *viz.* from September, 1786, to December, 1787, both inclusive, the variation may be considered as generally stationary at or about 7 or 8 o'clock in the morning when it is least; and about 1 or 2 o'clock in the afternoon when it is greatest; and therefore it has been the practice in determining the true variation put down in these tables, to take a mean of the two morning, and the two afternoon observations, made at those times, for the true variation.

In March, 1787. The mean monthly diurnal alteration of variation was found to be 15′,0; in June 19′,6; in July 19′,6; in September 14′,8; and in December 7′,6. But on a mean of 12 years observations, from the year 1793 to 1805, the diurnal alteration of variation in March was only 8′,5; in June 11′,2; in July 10′,6; in September 8′,7; and in December 3′,7.

Table IV. contains the differences for 12 years, *viz.* from 1793 to 1805, between the observations of the variation made in the months of March, June, September, and December, or at the times of the vernal and autumnal equinoxes, and summer and winter solstices; by a mean of these 12 years, the variation appears to increase or go westward, from the winter solstice to the vernal equinox 0′,80; diminishes or goes eastward from the vernal equinox, to the summer solstice 1′,43; increases again from the summer solstice to the autumnal equinox 2′,43; and continues nearly the same, only decreasing 0′,14, from the said equinox to the winter solstice.

These differences at the times of the equinoxes and solstices have been noticed by M. CASSINI, in his observations made at the Royal Observatory at Paris, between the years 1783 and 1788, but the effect was considerably greater in his observations, than in those mentioned above; his results however were, in my opinion, drawn from too few observations, being from only 8 days observations about the times of the equinoxes and solstices, which differ considerably among themselves; and experience teaches us, that magnetical observations made for a period so limited are not sufficient for minute purposes: I have therefore, in the results here given, taken the mean of the observations made during the whole month in which the equinoxes and solstices fall, which appear to me likely to furnish results more satisfactory; and all the foregoing observations are to be considered as the results or mean of a great many, by way of arriving at greater accuracy than could be obtained without; this, however, was found to be more necessary at some times than at others; sometimes, the needle would be extremely consistent with itself, so as to return exactly to the same point, however often it might have been drawn aside; at other times it varied 2 or 3′, sometimes 8, 10′, or even more; this uncertainty in the needle arises principally, I believe, from changes in the atmosphere, for, a change of wind, from any quarter to another, almost always produced a change in the needle from steady to unsteady, and *vice versâ*, but it was generally more unsteady with an easterly wind, than when it blew from any other quarter, and most steady when the wind was south or south-westerly. An Aurora Borealis always produced considerable agitation of the needle.

It has been mentioned in this Paper, that the annual increase of variation was found about the year 1775 to be nearly 10′; and was considered at that time to be gradually diminishing, but it is remarkable that this rate of increase appears from the annexed Table to be nearly the same at which it has been found to move between all the different periods in the said Table, from 1580 to 1787, a period of more than 200 years, excepting between the years 1692 and 1723; the observations of Dr. HALLEY in 1692 and Mr. GRAHAM in 1723 make the annual increase 16′; to what this difference could be owing I am at a loss to account; on referring to observations made at Paris for those two years the annual increase is 14′; subsequent observations made by Mr. GRAHAM in 1748 make the annual increase between this year and 1723 only 8′,1 nearly what its rate had been found before this great difference occurred; and from the variation of Mr. GRAHAM in 1748, and the variation observed by Dr. HEBERDEN in 1773, the annual increase is 8′,4; the variation in 1773 compared with the variation observed by myself in 1787, give for the annual rate of increase 9′,8; but between 1787 and 1795, the annual increase was only 4′,7; between 1795 and 1802, 1′,2; and between 1802 and 1805, only 0′,7.

The mean rate of annual increase for the above mentioned period of 207 years, *viz.* from 1580 to 1787, is 10′.

As there appears something curious in the rate at which the variation has been moving from observations made at London, for a period of more than 200 years, the annual increase of which during that time continued nearly the same, but in a subsequent period of 18 years only, the decrease of that annual increase became so rapid, that the annual increase in the latter part of it does not amount to quite one minute, I shall subjoin the following Table, by way of elucidating what is here mentioned.

By whom the Variation was observed.	Year.	Variation.	Annual Increase.
		° ′	′
Mr. BURROWS,* in - -	1580	11 15 E	
Mr. GUNTER - - -	1622	6 0	+ 7,5
Mr. GELLIBRAND - -	1634	4 6	9,6
Mr. BOND † - - -	1657	0 0	10,6
Mr. GELLIBRAND ‡ -	1665	1 22 W	10,2
Dr. HALLEY § - -	1672	2 30	9,7
———— - -	1692	6 0	10,5
Mr. GRAHAM ‖ - - -	1723	14 17	16,0
———— - -	1748	17 40	8,1
Dr. HEBERDEN ¶ - -	1773	21 9	8,4
Mr. GILPIN - - -	1787	23 19	9,3
———— - -	1795	23 57	4,7
———— - - -	1802	24 6	1,2
———— - -	1805	24 8	0,7

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[*] The observations of BURROWS, GUNTER, and GELLIBRAND'S, in 1634, are taken from SELLER'S Practical Navigation, 1676. BURROW'S observations are said to be the oldest and best in the world; longitude and latitude found by dipping needle, p. xvi. GELLIBRAND is said to be the first person who ascertained the variation of the variation, about the year 1625, Phil. Trans. No. 276—278; but if this is the date of the observations by which it was determined, the observations of GUNTER in 1622, show him to have a prior claim; BOND, in his Longitude found, p. 5 and 6, says that the variation was first found to decrease by Mr. JOHN MAIR, secondly by Mr. EDMUND GUNTER, thirdly by Mr. HENRY GELLIBRAND, and by himself in 1640.

[†] Longitude found, p. 3.

[‡] Ibid. p. 13; and Longitude and Latitude found by Dipping Needle, p. 6.

[§] Phil. Trans. No. 195, p. 565.

[‖] Ibid. No. 383, p. 107; and No. 488, p. 279.

[¶] Obligingly communicated by his son, the present Dr. HEBERDEN.

Table V. contains the dip of the magnetic needle from the years 1786 to 1805. For the first sixteen months, *viz.* from September, 1786, to December, 1787, both inclusive, the dip was observed as frequently as the variation, *but as there does not appear to be any diurnal alteration in the dip,* to make it at all interesting to communicate so many observations as were made, the mean therefore for each month has been thought sufficient for insertion.

To explain the foregoing Table it must be observed, that each of the numbers in the four first columns of the above Table, are each of them the mean of several means, as expressed in the line against those numbers; and as each of those means, are again the mean of five observations at least, each of the numbers in the first line, said to be the mean of nine means, is therefore a mean of forty-five observations; and so of all the rest.

The numbers in the fifth column, entitled true dip, are the means of the numbers contained in the four preceding columns in the same line with it.

The dipping needles used by Norman, the inventor of the dipping deedle, who observed the dip at London in the year 1576 to be* 71° 50′; and of Mr. Bond, who observed it in 1676 to be† 73° 47′; not being so much to be depended upon as the needles that have been in use for near a century past, render the progressive increase of the dip from Norman's time, to the time of its maximum, somewhat doubtful. But Mr. Whiston, whose needle there is reason to believe was more to be relied upon, in the year 1720 determined the dip to be* 75° 10′; this, when compared with many, and very accurate observations made by Mr. CAVENDISH, with several needles in the year† 1775, who found it to be 72° 30′, makes the decrease in this period of 55 years on a mean, 2′,9 *per annum*. And from a comparison of my own observations of the dip in 1805, which was 70° 21′, with the above of Mr. CAVENDISH in 1775, its annual decrease, on a mean, appears to have been 4′,3; and its progressive annual decrease on a mean in the above mentioned period of 30 years 1′,4.

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* New Attractive, c. 4.

† Longitude found.

I cannot conclude this Paper without expressing my regret, that so little avail should have been made of the numerous opportunities which have been afforded to travellers and others in the last century for making accurate observations with proper instruments, at land, on the variation in different parts of the world: such observations would probably have afforded some curious and useful facts which would have materially assisted in forming a theory much more certain than what we at present possess; the present received opinion of the cause of the diurnal alteration of variation would be confirmed or invalidated; its quantity of effect in different places, a most desirable acquisition, would be ascertained; and we should be put in possession of more valuable and correct information on the variation than can be derived from observations made with the common azimuth compass, even at land, owing to its imperfect construction. The variation thus accurately obtained at any one period, compared with the variation correctly ascertained at a subsequent period, would give a rate of alteration of the variation which could be relied on.

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* Longitude and Latitude found by Dipping Needle, p. 7—94.

† Phil. Trans. Vol. LXVI. p. 400.

The celebrated HALLEY thought the variation of so much importance, that he made two voyages for the purpose of making observations on the variation, to confirm his theory advanced in 1683, and soon after he published his variation chart. Since his time no better theory than he left has been obtained, although it must be confessed that many observations have been made at sea by voyagers; but these observations made generally to answer the purpose of the observer at the time only, are therefore seldom preserved; for unless made by authority, which rarely happens, they do not often meet the public eye; and it must be from observations made with care, and with good instruments, carefully registered, and properly arranged, that any real advantage can be derived. It is hoped therefore, that in future attention to this subject will not be thought beneath those who may have it in their power essentially to promote an undertaking so interesting to the philosopher, and so valuable and useful to the maritime world.

TABLE I.

Observations on the Variation of the magnetic Needle.

1786		7 A.M.		8 A.M.		10 A.M.		12 M.		1 P.M.		2 P.M.		4 P.M.		6 P.M.		8 P.M.		10 P.M.	
		°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′
Sep.	1	23	7	23	10	23	18	23	27	23	29	23	28	23	20	23	...	23	...	23	26
	2		9		10		14		20		21		21		...		...		...		14
	3		7		8		11		20		23		24		...		11		10		10
	4		9		9		16		22		23		23		...		...		...		12
	5		9		10		16		22		23		22		16		11		...		...
	6		6		6		15		23		24		23		...		14		...		8
	7		7		8		...		26		27		26		18		13		...		8
	8		23		23		18		23		23		23		...		16		13		...
	9		7		9		...		24		26		26		20		17		...		15
	10		15		16		...		28		28		26		...		...		...		14
	11		9		14		...		25		25		24		...		17		14		14
	12		3		...		15		26		18		...		...		17		17		16
	13		5		6		...		25		26		23		21		...		...		13
	14		4		...		...		19		22		26		...		...		15		14
	15		8		...		...		20		23		23		19		14		13		13
	16		8		10		...		20		22		22		...		...		12		9
	17		8		...		15		24		28		28		...		26		...		10
	18		6		7		13		19		19		20		...		18		15		14
	19		5		...		11		18		23		23		20		18		15		15
	20		8		...		11		21		23		24		16		15		14		12
	21		12		...		14		19		23		23		15		15		14		14
	22		11		...		14		20		23		23		18		16		13		13
	23		5		...		8		22		22		23		...		...		12		11
	24		3		...		11		20		23		24		20		15		13		11
	25		7		9		15		20		23		23		21		17		11		10
	26		5		...		14		21		24		26		22		14		11		10
	27		8		10		17		24		26		27		21		14		10		9
	28		5		6		13		18		19		19		20		18		15		5
	29		10		...		19		27		28		25		16		...		...		16
	30		9		...		21		24		24		24		20		16		21		10

TABLE I.

Observations on the Variation of the magnetic Needle.

1786	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Oct. 1	23 7	23 9	23 13	23 21	23 23	23 ...	23 ...	23 ...	23 12	23 10	23 ...
2	14	...	17	23	26	27	20	11	10	10	11
3	11	...	18	23	27	29	22	19	16	14	13
4	9	...	15	23	23	24	18	18	14	...	...
5	9	...	14	23	25	25	21	17	14	12	12
6	9	...	14	24	24	24	21	14	14	10	11
7	8	...	11	20	23	23	19	17	15	15	15
8	9	...	15	23	23	22	17	16	16	16	16
9	8	...	14	20	23	24	20	17	...	15	15
10	10	...	15	26	26	26	20	17	...	...	14
11	10	...	12	23	25	26	23	18	16	15	15
12	7	8	13	23	25	25	20	17	15	14	14
13	8	8	15	23	27	31	29	24	19	...	...
14	10	10	13	19	21	23	21	20	19	18	17
15	10	10	11	21	23	23	21	...	18	18	...
16	8	...	13	28	31	33	...	...	17	16	16
17	10	11	14	20	22	23	19	19	18	18	...
18	...	23	20	32	30	30	20	18	16	14	13
19	17	16	20	31	34	29	21	18	17	17	...
20	15	...	23	33	34	26	25	19	17	17	...
21	14	...	15	32	28	27	21	18	15	15	...
22	10	...	16	23	23	23	19	17	16	16	...
23	10	10	19	29	29	29	21	18	17	16	...
24	10	10	12	20	24	25	23	18	16	15	...
25	8	11	15	29	35	32	31	24	15	12	11
26	11	11	15	24	24	24	21	17	...	11	...
27	10	10	14	22	25	25	18	15	13	...	...
28	16	...	21	25	25	25	17	16	15	14	14
29	10	11	14	24	25	24	20	17	16	15	...
30	14	...	17	25	30	31	26	20	16	14	...
31	10	...	14	23	25	26	19	16	14	14	14

TABLE I.

Observations on the Variation of the magnetic Needle.

1786	7 A.M.		8 A.M.		10 A.M.		12 M.		1 P.M.		2 P.M.		4 P.M.		6 P.M.		8 P.M.		10 P.M.		11 P.M.	
	°	'	°	'	°	'	°	'	°	'	°	'	°	'	°	'	°	'	°	'	°	'
Nov. 1	23	13	23	13	23	19	23	32	23	34	23	...	23	...	23	...	23	...	23	...	23	...
2		10		...		11		19		21		20		19		17		15		14		...
3		10		10		15		23		22		21		21		20		16		16		...
4		10		11		14		18		20		21		19		18		15		15		15
5		10		10		16		22		23		22		19		17		17		17		17
6		12		13		15		21		22		22		20		18		18		18		14
7		10		...		15		21		23		23		21		18		17		16		...
8		11		...		17		25		25		25		22		19		16		13		...
9		13		...		16		23		24		24		20		17		...		13		13
10		11		11		14		21		22		22		20		16		15		13		13
11		11		11		15		21		21		20		17		16		15		15		15
12		11		11		15		20		21		20		17		...		...		15		15
13		13		13		17		23		21		23		21		18		16		15		15
14		11		11		14		20		20		21		20		18		16		15		15
15		16		...		22		24		23		22		20		17		16		15		15
16		10		...		11		19		19		20		19		17		...		16		...
17		13		...		13		18		20		19		20		18		16		17		...
18		15		...		14		20		20		22		22		18		16		14		...
19		12		13		13		23		24		24		22		17		15		17		...
20		11		11		13		18		23		23		22		18		14		13		15
21		12		...		18		21		21		21		21		19		16		16		...
22		13		...		18		21		23		23		21		17		16		15		15
23		13		...		16		22		24		24		23		18		...		14		...
24		13		14		14		19		21		21		19		16		14		14		...
25		14		14		15		21		22		22		21		18		17		16		16
26		...		14		15		22		23		23		20		18		16		15		15
27		15		15		19		23		24		24		20		...		16		16		...
28		...		14		15		23		...		...		...		...		17		16		...
29		15		15		16		22		23		23		21		18		16		15		...
30		14		14		15		...		...		...		21		...		17		15		15

TABLE I.

Observations on the Variation of the magnetic Needle.

1786	8 A.M.		10A.M.		12 M.		1 P.M.		2 P.M.		4 P.M.		6 P.M.		8 P.M.		10 P.M.		11 P.M.	
	°	'	°	'	°	'	°	'	°	'	°	'	°	'	°	'	°	'	°	'
Dec. 1	23	15	23	16	23	23	23	23	23	23	23	20	23	17	23	15	23	15	23	...
2		14		14		17		19		19		19		17		15		14		...
3		13		13		19		19		20		19		17		17		14		14
4		13		11		17		19		20		19		19		17		16		16
5		11		14		19		19		19		19		17		14		13		13
6		11		13		22		...		...		...		19		17		16		16
7		11		14		18		20		20		18		16		...		...		...
8		14		14		18		19		20		19		16		14		15		...
9		13		14		18		20		20		19		18		16		16		...
10		14		15		18		...		20		...		...		15		14		...
11		14		16		19		19		20		19		16		15		14		...
12		14		15		18		20		20		18		17		15		14		14
13		14		14		18		21		22		20		19		15		14		...
14		16		17		21		23		23		21		18		...		...		...
15		17		18		23		24		24		22		...		18		16		...
16		18		19		23		24		24		19		19		17		15		15
17		14		15		23		24		25		17		17		16		15		...
18		14		20		24		26		26		23		...		16		16		...
19		17		19		22		23		23		...		...		14		13		13
20		12		19		21		23		23		21		18		15		16		...
21		16		24		21		22		22		19		15		...		...		...
22		23		24		26		27		25		23		...		17		16		...
23		16		15		19		19		20		19		16		15		15		15
24		13		15		21		23		23		22		18		17		17		17
25		17		17		24		25		25		21		16		13		14		...
26		14		16		18		22		23		21		20		19		18		18
27		14		17		23		24		24		...		...		...		16		16
28		14		14		21		23		23		...		...		...		14		14
29		14		16		22		23		23		20		16		15		14		14
30		14		15		20		22		23		21		17		15		14		...
31		15		15		22		24		24		21		20		19		16		...

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Jan. 1	23 ...	23 15	23 19	23 23	23 24	23 24	23 21	23 16	23 ...	23 ...	23 ...
2	...	15	16	20	23	23	20	17	15	15	...
3	14	14	15	20	21	21	19	...	14	14	14
4	15	15	16	19	21	23	20	18	17	16	17
5	14	14	15	19	24	24	22	...	15	14	14
6	...	12	13	20	22	29	29	...	14	14	14
7	...	14	15	22	26	24	...	19	...	...	...
8	14	14	16	21	24	24	21	...	17	15	16
9	15	15	18	21	23	23	19	19	13	13	14
10	...	16	22	23	24	22	20	17	17	16	...
11	...	17	21	23	23	22	20	19	...	...	...
12	...	19	20	20	25	28	23	...	...	16	...
13	14	14	16	20	22	22	21	18	15	11	...
14	...	14	20	28	28	28	25	19	14	13	14
15	...	15	21	23	23	23	20	17	14	14	...
16	...	13	16	23	23	22	19	14	14	13	...
17	...	14	15	24	25	27	23	20	16	15	...
18	...	13	14	21	25	25	20	16	...	...	...
19	...	15	16	22	24	24	22	17	15	15	...
20	...	14	15	24	24	24	21	17	14	15	...
21	...	14	16	21	23	23	20	20	18	16	...
22	...	15	16	21	23	24	21	16	14	14	...
23	...	14	21	25	29	26	24	18	16	13	...
24	...	13	18	23	25	26	24	19	18	14	...
25	...	14	19	22	27	30	28	26	...	...	...
26	14	14	22	27	28	29	22	22	21	21	...
27	...	14	16	24	24	24	20	15	10	9	...
28	...	10	16	21	24	24	23	18	15	14	14
29	13	14	16	24	24	24	23	23	20	18	17
30	14	14	15	22	24	25	24	21	18	15	15
31	13	14	15	24	24	24	23	18	15	13	14

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.	12 P.M.
Feb. 1	23° 13′	23° 12′	23° 15′	23° 21′	23° 23′	23° 23′	23° 21′	23° 20′	23° ...	23° 17′	23° ...	23° 17′
2	16	16	17	20	20	20	21	19	19	18	...	...
3	16	16	21	22	24	25	31	27	19	14	14	...
4	16	16	19	25	26	26	23	18	16	16	...	...
5	16	16	17	22	25	25	24	18	16	14	14	...
6	14	14	16	23	23	24	23	21	16	10	...	...
7	...	16	18	27	26	24	24	17	16	10	...	9
8	...	17	16	21	25	25	20	16	...	14	...	...
9	14	13	15	23	23	23	23	21	17	16	...	16
10	17	17	18	22	25	25	22	17	15	11	11	13
11	13	14	15	23	27	26	21	15	11	10	10	...
12	15	16	14	23	22	23	21	19	18	16	16	...
13	13	12	16	25	25	23	20	16	13	12	12	...
14	11	11	14	22	23	23	20	...	...	...	...	...
15	13	15	17	24	31	30	28	20	...	10	...	...
16	...	16	17	24	25	25	23	21	18	17	...	...
17	...	28	28	28	28	28	20	18	...	17	...	...
18	...	16	17	22	24	24	24	19	16	16	16	...
19	9	9	9	20	22	22	21	18	16	15	...	...
20	...	18	12	25	27	28	29	20	15	10	...	...
21	...	21	23	26	26	26	25	...	16	13	...	12
22	12	11	19	21	24	23	23	16	...	...	...	...
23	15	15	21	...	...	31	29	...	11	10	10	...
24	14	14	17	23	26	29	25	18	14	13	13	...
25	13	13	15	28	29	30	29	25	...	23	...	...
26	23	23	23	24	24	23	...	19	16	12	12	...
27	12	12	17	24	25	26	24	18	14	12	...	...
28	14	13	14	21	22	22	...	15	9	14	...	13

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M	4 P.M.	6 P.M.	8 P.M.	10 P.M	11 P.M	12 P.M.
Mar. 1	23° 13′	23° 13′	23° 17′	3° 25′	23° 27′	23° 28′	23° 22′	23° 18′	23° ...	23° 11′	23° ...	23° ...
2	11	11	15	23	24	24	20	...	...	...	12	12
3	19	19	16	26	27	26	24	23	13	11	11	...
4	12	12	15	29	28	29	26	20	15	15	15	...
5	11	12	14	19	25	26	23	16	17	17	...	...
6	10	11	16	26	26	26	21	22	5	12	...	...
7	14	13	15	26	26	26	25	23	19	7	8	...
8	12	13	12	25	26	26	...	...	...	...	...	...
9	13	12	14	28	29	29	...	21	19	18	...	...
10	15	15	16	26	27	27	20	18	18	18	...	...
11	12	13	14	...	26	27	...	...	17	16	...	...
12	12	11	14	24	28	28	24	20	11	13	...	...
13	17	17	18	31	31	31	21	14	12	12	13	...
14	12	12	20	26	26	26	18	18	18	18	19	...
15	19	19	22	28	28	27	19	18	...	...	...	...
16	12	12	15	25	26	26	19	18	18	16	...	19
17	13	15	19	26	27	26	22	17	19	18	18	...
18	8	8	11	31	33	33	22	20	16	...	...	...
19	9	8	11	26	28	28	21	16	14	15	...	14
20	9	9	12	31	30	32	23	17	14	13	...	13
21	28	28	31	29	29	29	27	33	10	10	...	11
22	12	11	16	31	33	33	26	20	19	19	18	...
23	12	13	14	26	28	27	22	19	17	19	18	...
24	13	13	14	28	28	26	22	19	18	18	17	...
25	11	11	13	25	26	28	21	17	18	19	17	...
26	12	12	12	25	27	28	23	19	19	19	19	...
27	15	14	14	28	28	27	22	19	18	17	17	...
28	13	13	12	27	26	26	22	17	18	18	...	...
29	8	8	13	26	32	33	25	14	...	16	16	...
30	11	10	14	25	28	29	23	19	17	16	17	...
31	8	8	13	23	27	26	24	18	15	17	16	...

Table I.

Observations on the Variation of the magnetic Needle.

1787	6 A.M.	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
Apr. 1	23° ...	23° 12′	23° 12′	23° 16′	23° 24′	23° 26′	23° 28′	23° 26′	23° 21′	23° 19′	23° 19′	23° 18′
2	...	7	7	20	32	35	37	36	...	...	...	...
3	...	15	10	18	23	24	24	22	15	17	16	...
4	...	9	10	15	24	25	25	22	16	11	16	17
5	...	20	10	15	25	26	26	22	19	18	18	18
6	...	14	14	16	23	30	30	23	18	13	15	13
7	...	9	9	12	23	28	29	24	19	13	12	13
8	...	10	10	12	23	29	30	24	19	15	15	15
9	...	8	8	15	26	30	31	29	22	18	17	17
10	8	7	8	14	23	27	28	26	20	16	16	16
11	8	7	8	12	21	28	29	24	18	15	15	16
12	...	7	7	10	17	27	28	23	16	12	11	12
13	...	11	11	13	19	26	27	23	17	16	17	16
14	...	8	8	13	21	23	28	19	15	14	14	14
15	9	8	8	13	23	30	29	19	16	14	13	13
16	18	18	18	21	29	30	...	...	16	16	17	...
17	...	8	8	13	23	26	27	21	15	15	15	...
18	...	7	8	12	24	26	26	23	20	15	15	15
19	9	8	10	13	23	26	25	19	20	...	...	...
20	6	10	6	11	22	28	29	21	18	17	17	17
21	12	11	11	13	23	26	27	26	25	19	18	18
22	...	15	15	15	20	21	24	24	17	17	17	17
23	7	8	6	13	23	24	24	20	15	16	17	16
24	11	13	11	15	25	28	26	25	17	17	16	16
25	...	9	9	10	27	26	26	17	17	18	17	18
26	...	8	9	11	24	27	26	21	20	...	...	...
27	...	11	10	19	30	32	32	17	18	18	17	...
28	9	10	12	12	23	23	23	17	15	15	13	14
29	...	7	6	9	21	25	25	21	17	15	...	...
30	...	13	13	15	25	28	27	20	15	14	15	14

TABLE I.

Observations on the Variation of the magnetic Needle.

1787.	6 A.M.	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
May 1	23° 8′	23° 8′	23° 8′	23° 16′	23° 23′	23° 26′	23° 26′	23° 22′	23° 16′	23° 16′	23° 15′	23° 16′
2	8	8	8	15	25	25	25	21	20	19	18	17
3	11	11	11	14	23	27	26	21	15	...	...	...
4	6	5	6	13	28	29	29	23	17	16	16	16
5	7	8	7	11	25	26	26	21	17	15	15	16
6	9	7	7	17	28	27	28	25	18	17	18	17
7	9	8	8	13	25	28	28	21	19	19	9	14
8	7	8	7	17	25	26	26	22	17	13	15	14
9	...	...	...	18	30	30	30	26	20	19	19	20
10	2	4	3	23	32	30	27	18	18	...	17	26
11	6	6	6	11	24	23	24	20	17	17	16	17
12	9	8	8	11	23	24	24	20	17	16	17	17
13	6	5	5	11	24	25	25	...	...	15	14	13
14	11	10	6	10	38	38	31	27	26	18	17	17
15	13	11	11	13	25	26	26	16	19	18	17	19
16	8	8	9	14	22	25	25	23	24	23	26	24
17	10	11	10	13	17	21	21	17	17	...	...	...
18	8	9	9	13	28	29	29	24	15	15	15	15
19	4	3	3	9	22	25	25	24	16	14	16	...
20	9	7	7	11	23	25	25	19	19	19	19	18
21	10	10	11	14	28	30	27	26	23	22	22	21
22	10	11	10	13	26	27	27	21	15	14	16	15
23	10	9	9	14	24	26	26	21	15	16	16	17
24	6	6	6	12	24	25	25	16	16	16	...	...
25	7	7	7	16	25	26	27	21	15	17	16	16
26	5	5	7	14	24	25	25	19	17	17	17	17
27	7	7	8	14	23	26	26	...	...	17	17	17
28	6	5	5	10	23	25	25	20	17	17	17	17
29	8	8	10	13	24	26	26	19	19	19	18	19
30	5	6	6	14	26	27	27	19	16	16	16	17
31	4	5	4	11	24	26	27	19	16	18	15	17

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	6 A.M	7 A.M.	8 A.M.	10 A.M	12 M.	1 P. M.	2 P. M.	4 P. M.	6 P. M	8 P. M.	10 P. M	11 P. M.
June 1	23° 8′	23° 7′	23° 7′	23° 11′	23° 26′	23° 28′	23° 28′	23° 22′	23° 17′	23° 16′	23° 18′	23° 17′
2	6	6	6	17	24	25	25	20	19	17	18	17
3	6	6	6	18	28	28	27	24	20	18	19	18
4	6	5	7	13	24	26	25	21	19	16	15	16
5	6	6	5	16	29	28	29	22	19	17	16	17
6	7	6	8	17	29	30	30	24	19	19	16	15
7	5	5	5	13	25	30	30	27	22	17	...	16
8	7	8	8	19	28	28	28	27	20	16	15	16
9	18	17	19	21	26	26	26	19	17	17	17	17
10	16	15	16	20	24	26	26	22	19	18	19	19
11	6	7	6	16	28	27	27	20	19	19	18	19
12	6	6	6	15	28	29	29	26	19	19	19	19
13	6	5	6	13	25	27	27	23	20	19	19	19
14	6	6	7	14	26	30	31	24	20	16	...	16
15	3	5	5	10	28	31	32	25	20	20	20	20
16	6	5	6	15	28	31	33	26	17	17	16	18
17	8	8	10	11	28	31	30	25	18	19	16	17
18	9	8	10	16	29	31	31	26	18	18	18	17
19	6	5	5	13	26	27	27	24	17	17	18	17
20	14	13	14	21	31	32	32	24	19	17	16	18
21	8	9	8	18	26	29	29	24	19	19	...	18
22	11	11	10	18	29	29	29	24	19	18	19	18
23	8	8	10	18	26	26	26	20	19	19	19	19
24	6	6	6	16	23	28	29	22	19	19	19	19
25	19	19	19	19	28	28	29	21	19	18	18	18
26	8	7	7	15	23	23	23	18	18	19	18	18
27	9	11	9	14	28	30	29	18	18	18	18	18
28	10	9	11	19	26	28	26	19	16	17	...	...
29	9	9	13	18	26	26	25	20	18	17	19	18
30	10	8	10	17	24	26	26	21	18	20	18	18

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	6 A.M	7 A.M	8 A.M.	10 A.M.	12 M.	1 P. M.	2 P. M.	4 P. M.	6 P. M.	8 P. M.	10 P. M.	11 P. M.
	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '
July 1	23 9	23 9	23 11	23 18	23 26	23 26	23 25	23 19	23 16	23 17	23 16	23 16
2	9	10	9	15	29	29	28	22	17	16	17	17
3	5	5	7	12	27	27	27	22	17	17	16	17
4	8	7	11	17	28	30	29	22	19	16	16	17
5	8	7	8	11	28	30	30	21	17	17	18	17
6	7	7	8	22	25	27	27	21	19	20	18	19
7	8	6	7	16	27	28	28	22	18	18	18	18
8	6	7	8	15	25	27	27	21	18	18	18	19
9	7	8	7	15	25	27	27	22	20	20	20	20
10	5	5	5	15	24	24	24	23	20	20	20	20
11	7	7	8	17	26	27	27	26	23	19	19	19
12	5	5	7	14	30	33	33	23	21	20	19	19
13	10	10	10	17	30	30	30	24	19	19	19	20
14	10	10	11	19	28	29	30	23	20	17	18	18
15	11	11	13	20	28	29	29	22	20	18	21	18
16	10	11	13	18	25	29	27	24	23	23	23	23
17	8	6	8	21	30	35	36	26	18	19	20	19
18	9	9	11	14	25	29	29	26	19	...	18	19
19	9	8	11	19	25	29	29	25	20	19	20	20
20	9	9	10	20	28	29	29	25	20	21	20	20
21	7	8	8	20	29	30	30	25	19	18	20	19
22	8	10	8	19	29	30	30	24	20	18	22	19
23	15	17	16	16	28	30	30	26	23	22	23	22
24	8	8	8	16	28	31	33	27	21	21	22	21
25	13	16	14	18	28	31	33	20	20	20	20	20
26	14	14	14	15	26	30	31	24	21	21	22	21
27	14	14	15	22	...	...	...	...	...	...	20	20
28	14	15	14	26	30	30	31	23	19	19	21	20
29	16	16	16	21	31	32	31	20	18	18	19	19
30	13	12	13	23	30	30	32	26	19	18	19	18
31	12	11	12	22	29	30	30	...	...	...	...	...

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	6 A. M.	7 A. M.	8 A. M.	10 A. M.	12 M.	1 P. M.	2 P. M.	4 P. M.	6 P. M.	8 P. M.	10 P. M.	11 P. M.
Aug. 1	23° 8′	23° 9′	23° 13′	23° 19′	23° 38′	23° 39′	23° 39′	23° 36′	23° 23′	23° 18′	23° 17′	23° 17′
2	7	8	17	21	31	31	31	24	19	19	18	19
3	9	8	13	18	28	34	35	24	19	18	19	17
4	11	13	12	18	31	31	31	23	19	19	21	19
5	13	12	11	15	28	33	32	26	...	...	19	20
6	11	10	12	17	26	31	33	27	21	21	21	20
7	10	11	10	16	26	30	33	28	21	20	20	21
8	9	9	10	17	30	32	32	29	21	21	19	21
9	11	13	12	17	30	31	30	25	19	19	19	20
10	13	12	14	22	31	33	34	29	18	16	19	16
11	10	14	11	20	32	32	32	26	15	15	15	17
12	15	13	14	20	28	31	30	25	19	19	19	19
13	8	11	10	17	29	30	30	24	19	19	19	19
14	10	10	10	20	30	31	31	23	19	18	17	16
15	10	10	9	19	38	38	35	29	20	19	19	20
16	13	14	12	21	33	35	33	29	19	19	19	19
17	8	7	9	18	29	30	30	25	20	19	18	18
18	7	7	8	21	28	29	29	28	21	19	17	19
19	8	8	9	20	31	...	...	...	...	...	19	19
20	21	21	20	29	35	34	31	27	19	19	21	20
21	21	20	21	29	34	33	32	24	19	21	19	20
22	13	13	14	17	27	29	29	25	20	18	19	19
23	13	12	13	17	29	30	30	24	19	17	18	18
24	11	11	13	17	29	30	29	23	21	19	21	22
25	21	20	21	25	31	31	31	22	19	19	20	19
26	12	14	13	18	28	30	30	...	18	19	19	18
27	14	14	15	21	29	29	29	21	17	18	18	18
28	12	12	13	18	29	30	30	25	21	19	21	...
29	14	14	14	21	30	31	32	25	18	18	18	18
30	12	11	12	19	29	31	31	22	19	18	19	17
31	13	12	13	23	33	31	31	23	19	18	18	20

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	6 A.M.	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Sep. 1	23 13	23 14	23 14	23 23	23 33	23 34	23 35	23 26	23 20	23 21	23 20	23 20
2	13	13	14	21	31	32	32	...	21	20	20	20
3	14	14	14	22	33	33	32	26	21	20	21	19
4	13	13	15	19	29	31	31	25	19	21	20	20
5	14	13	14	18	29	30	30	26	21	17	19	19
6	14	14	15	21	29	31	31	28	21	19	19	21
7	19	19	20	26	33	35	34	31	21	16	17	17
8	15	16	15	21	28	30	29	24	18	17	17	17
9	15	16	16	21	30	30	29	...	20	18	19	19
10	14	14	14	22	30	30	30	23	19	18	18	18
11	13	14	14	21	29	29	29	22	19	20	19	18
12	12	11	14	18	30	30	29	23	18	18	19	19
13	13	15	14	18	29	30	30	22	19	19	19	19
14	14	15	15	21	30	30	30	25	20	19	18	20
15	15	14	14	20	32	33	33	26	19	19	20	19
16	13	13	15	21	36	35	36	23	18	19	19	18
17	16	14	20	18	28	36	36	...	23	19	20	20
18	19	20	15	23	35	31	33	26	22	21	21	20
19	16	16	16	21	27	29	29	...	...	20	19	20
20	16	18	14	23	27	29	28	23	21	19	20	20
21	16	16	14	21	28	30	28	24	21	20	18	19
22	17	17	13	22	29	28	28	23	21	20	19	20
23	16	16	14	21	28	29	29	21	18	18	18	18
24	18	17	15	22	29	31	31	26	20	20	21	19
25	18	19	14	26	31	32	29	25	21	20	20	21
26	17	17	13	21	28	27	27	21	17	16	16	16
27	16	16	14	20	29	30	30	26	22	18	20	19
28	15	14	19	18	26	28	27	22	19	19	19	19
29	13	13	17	20	27	28	28	26	22	21	21	21
30	14	13	17	16	31	30	31	29	23	21	21	22

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	7 A.M	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Oct. 1	23 17	23 17	23 23	23 32	23 32	23 32	23 29	23 21	23 21	23 21	23 ...
2	19	19	19	30	30	30	26	21	20	20	...
3	18	18	24	30	33	33	23	21	21	21	21
4	14	14	21	30	33	33	26	21	21	12	...
5	18	17	25	31	35	34	31	17	13	14	13
6	15	15	19	29	31	31	27	21	19	19	20
7	15	15	...	30	31	31	27	22	21	21	...
8	15	15	22	30	30	30	26	20	20	20	...
9	14	14	19	29	31	32	27	21	20	21	...
10	15	16	21	33	34	34	30	21	21	21	...
11	19	17	26	33	34	33	...	25	21	19	...
12	16	17	23	30	31	30	26	23	22	23	...
13	18	16	18	29	29	29	...	...	...	...	...
14	21	21	27	31	32	32	...	22	20	20	...
15	16	15	19	28	31	31	28	21	22	20	...
16	16	16	18	27	28	28	27	24	24	22	...
17	15	18	16	26	26	26	26	23	24	21	...
18	17	17	17	28	26	31	27	21	20	20	...
19	17	16	21	26	28	28	27	24	22	22	...
20	17	17	18	29	29	29	26	19	20	19	...
21	16	16	18	29	30	30	...	22	19	21	...
22	18	17	18	31	33	32	...	...	20	20	...
23	17	16	19	30	30	29	23	21	19	20	...
24	18	19	20	33	33	31	33	23	21	17	...
25	23	18	23	37	38	37	34	23	23	22	...
26	21	22	26	35	37	35	28	22	24	25	...
27	26	28	27	35	35	33	28	22	21	22	...
28	19	18	24	34	35	33	...	...	21	20	21
29	18	18	21	34	35	35	24	21	22	21	...
30	18	18	23	35	35	35	28	22	22	21	22
31	16	15	19	32	34	34	29	29	...	...	...

TABLE I.

Observations on the Variation of the magnetic Needle.

1787	7 A. M.	8 A. M.	10 A. M.	12 M.	1 P. M.	2 P. M.	4 P. M.	6 P. M.	8 P. M.	10 P. M.	11 P. M.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Nov. 1	23 21	23 20	23 21	23 30	23 30	23 28	23 27	23 22	23 18	23 20	23 ...
2	17	20	20	28	31	28	26	22	20	22	23
3	20	20	21	27	37	35	31	22	23	22	...
4	18	18	...	35	36	35	28	21	22	22	21
5	17	18	21	35	35	35	32	24	21	18	...
6	18	18	19	35	35	33	30	22	21	20	20
7	17	17	19	30	33	33	26	20	22	20	21
8	17	17	19	30	33	33	26	20	22	20	21
9	17	18	20	30	33	33	31	31	...	22	...
10	18	17	19	31	33	33	31	28	22	22	23
11	20	20	21	31	34	35	32	...	20	22	22
12	18	20	19	28	31	32	28	21	22	21	...
13	18	19	19	28	29	30	28	22	21	21	22
14	18	18	20	28	29	29	25	22	21	22	22
15	20	19	20	28	28	28	27	25	...	23	23
16	19	19	20	27	26	28	26	19	17	20	20
17	20	19	20	26	28	27	25	21	20	21	20
18	19	19	20	29	29	29	...	25	24	...	...
19	22	23	23	31	32	31	31	26	22	22	21
20	23	22	23	31	33	32	29	22	21	21	22
21	21	23	23	28	29	29	26	22	21	22	23
22	21	20	21	31	29	30	29	23	...	22	22
23	21	21	21	29	28	29	26	22	23	22	...
24	22	20	21	30	31	30	26	22	22	20	21
25	22	22	22	30	30	30	...	...	22	21	...
26	20	21	21	30	29	31	26	22	23	...	...
27	21	22	21	28	30	29	26	23	23	22	...
28	19	21	20	26	27	27	26	23	22	23	...
29	21	20	21	31	31	29	25	23	22	22	...
30	22	21	23	31	34	33	28	22	21	22	...

TABLE I.

Observations on the Variation of the magnetic Needle,

1787	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Dec. 1	23 21	23 21	23 20	23 29	23 31	23 30	23 28	23 22	23 23	23 22	23 22
2	20	21	21	31	31	31	27	23	22	21	22
3	21	20	21	30	31	29	26	22	22	23	...
4	21	22	22	30	31	31	...	...	22	21	...
5	18	20	21	28	31	26	26	22	21	23	...
6	22	22	23	29	29	30	28	24	23	21	...
7	21	21	22	28	30	29	26	23	23	22	22
8	20	21	21	26	28	29	29	26	22	22	...
9	22	20	21	26	31	30	26	26	21	22	...
10	21	21	21	29	29	29	25	23	21	22	21
11	18	21	22	28	29	31	28	21	23	21	...
12	20	20	21	33	33	33	31	24	24	19	...
13	...	21	21	28	30	30	27	25	...	22	...
14	21	21	26	30	31	33	...	...	...	22	...
15	20	22	22	30	31	30	27	21	23	20	...
16	...	22	29	31	28	31	...	25	22	22	...
17	...	22	23	31	33	33	...	23	22	23	21
18	...	21	20	28	29	29	28	23	24	22	...
19	...	19	22	29	28	27	25	23	22	23	...
20	...	21	24	28	30	29	26	24	24	24	...
21	...	23	26	29	29	29	25	22	22	22	...
22	...	21	21	24	26	24	22	25	20	19	...
23	...	19	21	24	24	24	...	20	20	19	...
24	...	20	20	29	30	29	24	24	22	22	...
25	...	22	20	28	28	28	26	22	20	21	...
26	...	22	22	29	33	29	26	22	23	22	...
27	...	21	21	24	26	26	23	21	21	21	...
28	...	21	21	25	25	26	24	23	20	21	...
29	...	20	20	23	22	25	25	20	20	21	...
30	...	21	21	...	25	30	29	...	...	...	...
31	...	21	20	29	26	28	25	22	22	...	...

TABLE II.

Mean monthly Variation of the magnetic Needle.

1786	6 A.M.	7 A.M.	8 A.M.	10 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	11 P.M.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Sept.	23	23 7,9	23 10,1	23 14,5	23 22,2	23 23,7	23 23,9	23 19,0	23 15,3	23 13,5	23 12,4	23 ....
Oct.	. . .	10,4	11,3	15,2	24,4	26,1	26,1	21,1	17,7	15,6	14,5	13,8
Nov.	. . .	12,2	12,5	15,3	21,6	22,5	22,0	20,3	17,6	15,9	15,1	14,7
Dec.	. . .	. . .	14,5	16,1	20,6	22,0	22,2	20,0	17,4	15,8	15,0	15,0
1787												
Jan	. . .	14,0	14,2	17,1	22,3	24,1	24,5	21,8	18,4	15,6	14,5	14,8
Feb.	. . .	14,2	15,1	17,1	23,3	24,8	25,1	23,6	18,8	15,3	15,8	12,8
Mar.	. . .	12,8	12,8	15.3	26,5	27,7	27,8	18,4	19,0	15,9	15,5	15,7
April	9,7	9,9	9,7	13,9	23,6	27,0	27,4	22,6	17,8	15,7	15,7	15,6
May	7,6	7,5	7,4	13,5	25,2	26,6	26,2	21,0	17,7	17,1	16,8	17,0
June	8,4	8,2	8,8	16,0	26,6	28,1	28,1	22.6	18,7	17,9	17,8	17,7
July	9,5	9,6	10,3	17,8	27,6	29,3	29.4	23,2	19,4	18,9	19,3	19,1
Aug.	11,9	12,0	12,8	19,7	30,3	31,7	31,5	25,6	19,3	18,7	18,9	18,8
Sept.	15,0	15,1	15,3	20,2	29,8	30,7	30,5	24,7	20,1	19,1	19,2	19,2
Oct.	. . .	17,5	17,3	21,1	30,8	31,9	31,6	27,4	21,9	20,8	20,2	19,6
Nov.	. . .	19,4	19,7	20,6	29,7	31,1	30,2	27,7	22,7	21,4	21,3	21,4
Dec.	. . .	20,4	21,0	21,8	28,2	29,0	29,0	26,2	22,9	21,9	21,6	. . .

TABLE III.

Mean monthly true Variation, and mean monthly diurnal Alteration of Variation of the magnetic Needle.

	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.
	January.		February.		March.		April.		May.		June.	
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1786	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
1787	23 19,2	10,2	23 19,8	10,4	23 20,3	15,0	23 18,5	17,4	23 17,0	18,9	23 18,3	19,6
1788	23 25,6	8,7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	23 28,9	18,8
1789	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	23 34,2	17,1
1790	23 38,9	8,4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
1791	23 35,6	6,8	. . .	. . .	. . .	. . .	23 36,0	15,0	. . .	. . .	. . .	. . .
1792	23 41,1	5,4	. . .	. . .	. . .	. . .	. . .	. . .	23 41,9	11,5	. . .	. . .
1793	23 46,9	4,3	23 48,3	4,6	23 48,8	8,5	23 46,2	11,7	23 47,3	10,4	23 48,5	12,6
1794	23 54,2	4,5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
1795	. . .	. . .	. . .	. . .	23 57,5	9,8	. . .	. . .	. . .	. . .	23 57,1	9,4
1796	. . .	. . .	. . .	. . .	24 1,1	7,0	. . .	. . .	. . .	. . .	23 58,7	9,8
1797	. . .	. . .	. . .	. . .	24 1,5	7,4	. . .	. . .	. . .	. . .	24 0,2	11,6
1798	. . .	. . .	. . .	. . .	24 0,6	7,2	. . .	. . .	. . .	. . .	23 59,4	11,2
1799	. . .	. . .	. . .	. . .	24 1,1	7,5	. . .	. . .	. . .	. . .	24 0,6	10,8
1800	. . .	. . .	. . .	. . .	24 3,6	6,9	. . .	. . .	. . .	. . .	24 1,8	10,9
1801	. . .	. . .	. . .	. . .	24 5,2	8,8	. . .	. . .	. . .	. . .	24 2,8	10,8
1802	. . .	. . .	. . .	. . .	24 6,9	9,5	. . .	. . .	. . .	. . .	24 5,3	10,7
1803	. . .	. . .	. . .	. . .	24 8,0	11,8	. . .	. . .	. . .	. . .	24 7,0	12,6
1804	. . .	. . .	. . .	. . .	24 9,4	10,0	. . .	. . .	. . .	. . .	24 6,0	11,3
1805	. . .	. . .	. . .	. . .	24 8,7	8,1	. . .	. . .	. . .	. . .	24 7,8	12,5

TABLE III.

Mean monthly true Variation, and mean monthly diurnal Alteration of Variation of the magnetic Needle.

	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.	True Variation.	Diurnal Alteration of Variation.
	July.		August.		September.		October.		November.		December.	
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1786	. . .	. . .	. . .	. . .	23 16,4	14,8	23 18,4	15,3	23 17,3	9,9	23 18,3	7,6
1787	23 19,6	19,6	23 21,9	19,4	23 22,8	15,5	23 24,5	14,3	23 25,0	11,1	23 25,8	8,3
1788	23 29,8	16,4	. . .	. . .	. . .	. . .	23 32,1	14,6	. . .	. . .	. . .	. . .
1789	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	23 41,2	5,4
1790	23 39,0	15,4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
1791	23 36,7	15,2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
1792	. . .	. . .	23 43,6	12,7	23 43,9	11,1	23 45,6	8,9	23 45,9	3,7	23 45,2	3,1
1793	23 50,5	12,5	23 48,6	12,1	23 52,6	9,8	23 52,3	7,0	23 51,9	3,8	23 52,3	3,8
1794	23 54,4	11,2	23 57,2	9,8	23 58,1	8,4	. . .	. . .	. . .	. . .	. . .	. . .
1795	23 57,1	8,4	. . .	. . .	24 0,4	7,6	. . .	. . .	. . .	. . .	23 59,4	3,6
1796	23 59,2	10,1	. . .	. . .	24 0,1	8,3	. . .	. . .	. . .	. . .	24 1,3	4,9
1797	24 0,3	10,1	. . .	. . .	24 1,4	7,6	. . .	. . .	. . .	. . .	24 1,3	5,0
1798	24 0,0	10,0	. . .	. . .	24 1,4	9,4	. . .	. . .	. . .	. . .	24 1,4	2,7
1799	24 1,8	10,4	. . .	. . .	24 2,9	7,8	. . .	. . .	. . .	. . .	24 2,3	3,4
1800	24 3,0	9,2	. . .	. . .	24 3,6	7,7	. . .	. . .	. . .	. . .	24 3,3	3,1
1801	24 4,1	10,3	. . .	. . .	24 3,8	10,1	. . .	. . .	. . .	. . .	24 5,4	2,5
1802	24 6,0	12,3	. . .	. . .	24 8,7	8,9	. . .	. . .	. . .	. . .	24 6,8	3,8
1803	24 7,9	13,1	. . .	. . .	24 10,5	9,5	. . .	. . .	. . .	. . .	24 10,7	3,0
1804	24 8,4	10,4	. . .	. . .	24 8,9	9,3	. . .	. . .	. . .	. . .	24 9,0	3,7
1805	24 7,8	10,4	. . .	. . .	24 10,0	9,3	. . .	. . .	. . .	. . .	24 9,4	4,6

TABLE IV.

Differences between the Observations of the Variation of the magnetic Needle at the Times of the Equinoxes and those at the Solstices.

Years.	March.	June.	September.	December.
1793	+ 3',6	— 0',3	+ 4',1	— 0',3
1795	. . . .	— 0,4	+ 3,3	— 1,0
1796	+ 1,7	— 2,4	+ 1,4	+ 1,2
1797	+ 0,2	— 1,3	+ 1,2	— 0,1
1798	— 0,7	— 1,2	+ 2,0	0,0
1799	— 0,3	— 0,5	+ 2,3	— 0,6
1800	+ 1,3	— 1,8	+ 1,8	— 0,3
1801	+ 1,9	— 2,4	+ 1,0	+ 1,6
1802	+ 1,5	— 1,6	+ 3,4	— 1,9
1803	+ 1,2	— 1,0	+ 3,5	+ 0,2
1804	— 1,3	— 3,4	+ 2,9	+ 0,1
1805	— 0,3	— 0,9	+ 2,2	— 0,6
Mean	+0',80	—1',43	+2',43	—0',14

TABLE V.

Dip of the magnetic Needle.

			Poles reversed.			
	Face East.	Face West.	Face East.	Face West.	True Dip.	
	° ′	° ′	° ′	° ′	° ′	
1786						
September	72 28,7	72 1,4	71 57,3	72 5,1	72 8,1	Mean of 9 means.
October	72 29,9	71 59,0	72 0,4	72 1,2	72 7,6	—— 7 ——
November	72 7,6	72 17,6	72 2,4	71 46,7	72 3,6	—— 6 ——
December	72 10,6	72 2,2	72 2,2	71 58,4	72 3,4	—— 6 ——
1787						
January	72 11,4	72 1,8	72 1,0	71 56,0	72 2,5	—— 11 ——
February	72 19,4	72 10,8	72 1,5	71 55,8	72 6,9	—— 12 ——
March -	72 19,1	72 11,9	72 0,5	71 52,2	72 5,9	—— 14 ——
April -	72 24,4	72 9,5	72 0,5	71 52,2	72 6,6	—— 14 ——
May -	72 24,4	72 9,6	72 4,2	71 52,9	72 7,8	—— 15 ——
June -	72 22,6	72 7,9	72 4,2	71 52,9	72 6,8	—— 15 ——
July -	72 22,6	72 7,9	71 59,9	71 55,1	72 6,4	—— 15 ——
August	72 22,3	72 6,7	71 59,3	71 55,2	72 5,9	—— 15 ——
September	72 22,3	72 6,7	72 2,9	71 51,0	72 5,7	—— 15 ——
October	72 23,1	72 2,5	72 2,9	71 51,0	72 4,9	—— 15 ——
November	72 23,1	72 2,5	72 2,7	71 50,3	72 4,7	—— 15 ——
December	72 22,8	72 2,0	72 2,7	71 50,3	72 4,4	—— 15 ——
1788						
January	72 22,8	72 2,0	72 2,6	71 48,8	72 4,0	—— 15 ——
1789						
January	72 16,0	72 0,0	71 51,9	71 31,1	71 54,8	—— 4 ——
December	72 17,5	71 59,4	71 38,9	71 42,8	71 54,6	—— 4 ——
1790						
January	72 16,9	71 57,7	71 40,2	71 40,2	71 53,7	—— 7 ——
1791						
January	71 43,9	71 36,1	71 37,2	71 17,5	71 23,7	—— 4 ——
1795						
October	71 12,8	71 9,5	71 13,9	71 9,4	71 11,4	—— 14 ——
1797						
October	71 4,9	71 10,9	70 56,3	70 44,7	70 59,2	—— 30 ——
1798						
April -	71 4,7	71 14,5	71 2,3	70 19,8	70 55,4	—— 16 ——
October	70 55,6	71 14,5	71 7,7	70 22,2	70 55,0	—— 16 ——
1799						
October	70 56,0	71 13,5	71 11,5	70 7,9	70 52,2	—— 16 ——
1801						
April -	70 47,4	71 5,6	70 52,4	69 38,2	70 35,6	—— 16 ——
1803						
October	70 30,9	71 9,9	70 40,5	69 46,7	70 32,0	—— 16 ——
1805						
August -	70 25,2	70 55,7	70 26,9	69 36,3	70 21,0	—— 16 ——

Year		Variation of Magnetic Needle	Dip
Sep.	1786	23.16.4 W.	Sep 72.8,1
	1787	[illegible].3	[illegible]5,7
	1788	28.9	Jan 72.4
	1789	34.2	71.54,2
July	1790	39.0	50,7
	1791	36.7	[illegible]3,7
May	92	41.9	
June	93	48.5	
July	94	54.4	
June	95	57.1	Oct. 71.14.4
	96	58.7	
	97	24. 0.12	Oct. 70.59.2
	98	23.59.4	Oct. 70.55,0
	1799	24. 0.6	52,2
	1800	24. 1.8	
	1801	2.8	Apr 70.35,6
	1802	5.3	
	1803	7.0	Oct. 70.32,0
	04	6.0	
	05	7.8	Aug. 70.21.0
	06	8,6	
Sep.	07	10.2	
June	08	10.0	June 70.1.0
	09	11.0	
	1810		
Sep.	11	14.2	Sep. 70.32.30
Oct.	12	16,30	
Sep.	13	16,40	
	14		
June	15	17.50	
	16	Maximum 17.54	
	17	17.0	
	18	15.43	June 70.51.0
	19	14.47	
	20	11.44	June 71.6.0
	21	11.18	
	22	9.55	
	23	9.48	
	24		
	1825		

The Variation of the Magnetic Needle in the Island of Jamaica is 6°½ East & has remained the same since the Year 1660. by old Surveys.

XXI. *On the Declinations of some of the principal fixed Stars; with a Description of an Astronomical Circle, and some Remarks on the Construction of Circular Instruments. By* John Pond, *Esq. Communicated by* Smithson Tennant, *Esq. F. R. S.*

Read June 26, 1806.

THE observations which accompany this Paper were made at Westbury in Somersetshire, in the years 1800 and 1801, with an Astronomical Circle of two feet and a half diameter, constructed by Mr. TROUGHTON, and considered by him as one of the best divided instruments he had ever made; a drawing of it, with a short description, is annexed to the observations. (Plate XX.)

When this instrument came into my possession, I thought I could not employ it in a more advantageous manner, than in endeavouring to determine the declinations of some of the principal fixed stars.* The various catalogues differed so much from each other, and such doubt existed as to the accuracy of those which were thought most perfect; that the declinations of few stars could be considered as sufficiently well ascertained for the more accurate purposes of astronomy.

The advantages that have resulted from the excellent method pursued at Greenwich, of observing constantly the transits of a few stars, to obtain accurately their right ascensions, induced me to follow the same method for determining their declinations; and for a considerable period I constantly observed them on the meridian, whenever they passed at a convenient hour; usually reversing the instrument in azimuth at the end of every day's observation; never considering any observation as complete that had not its corresponding one in a short interval of time. When this circumstance is not attended to, I think, a great part of the advantage arising from the circular construction is lost.

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* At that time Dr. MASKELYNE's late Catalogue was not published.

The observations themselves will show, if they have been made with the requisite care and attention to merit the notice of astronomers; for it is one of the many advantages of circular instruments, that from the observations made with them, we may infer with great precision not only the mean probable error, but likewise the greatest possible error to which they are liable. From a careful comparison of the errors of collimation, as deduced from different stars, I concluded that the greatest possible error was 2″,5, and the mean error about 1″; and by a comparison with other observations with similar instruments, it will be seen that this supposition was well founded, since nearly the same quantities are deduced by another method to be considered hereafter.

The polar distances are annexed to each observation: a method which I borrowed from Mr. Wollaston, and which is rendered very easy by employing his useful tables calculated for that purpose. This practice of reducing every day's observations cannot be too much recommended, as the labour of calculating accumulated observations is thus rendered unnecessary.

When I had deduced the declinations of these stars from my own observations, continued long enough to divest them of all error, except that arising from defect in the divisions of the intrument, I was desirous of comparing them with the observations made by others; and I have subjoined a comparison of them with all those which I could procure, that seemed entitled to confidence. In the first column are the observations made at Greenwich, as published in 1802 by the Astronomer Royal; the second column contains a catalogue deduced from some observations made at Armagh with a very large equatorial instrument constructed by Mr. Troughton. In the third column are the observations of Mr. Piazzi, of Palermo; and in the fourth those made at Westbury. All the above mentioned observations are arranged in the order of their polar distances, and the positive deviations separated from the negative; that the cause of error in any of the instruments may be the more easily detected, as likewise any mistake in the assumed latitudes of the respective places of observation.

A general catalogue is then added; which is deduced, by taking the mean, generally of the above four; but in some places, a few detached observations that I have accidentally procured of other circular instruments have been included. The utility of this investigation is not merely confined to the determination of the polar distances of the stars; as besides this some valuable information on other points may be obtained. In the first place, upon examining the variations that appear in these observations a question naturally occurs, whether, by changing the assumed latitudes of the respective places of observation, a nearer coincidence might not be obtained. And I find, that to make the positive deviations equal to the negative, the following corrections should be applied to the co-latitudes.

Greenwich	+ 1″
Armagh	+ 1″,3
Palermo	− 1″
Westbury	− 0″,25.

This method of correcting the latitudes has, I believe, never been employed: but it seems reasonable to suppose, that when thus corrected, they will be nearer the truth, than those determined by the usual method: for the same reason, that the declinations of the stars resulting from a general comparison, are more likely to be accurate, than if deduced from any one single set of observations: but if the Greenwich instrument should be affected with any errors independent of the divisions; in that case, we should be unable to infer any thing decisive, as to the latitude, by the above method. But from a comparison of the observations of γ Draconis, observed at Greenwich and Westbury, the latitude of Westbury being previously corrected by the above method, I am inclined to believe the latitude of Greenwich requires a very small correction, certainly not exceeding a second. The result I obtain by a very careful investigation by methods, entirely independent of the Greenwich quadrant, is 51°.28′.39″,4.

I consider this comparison as interesting likewise on another account; it is an object deserving of curiosity to examine the present state of our best astronomical instruments, and to ascertain what may reasonably be expected from them. The superiority of circular instruments is, I believe, too universally admitted, to render it probable that quadrants will ever again be substituted in their place. But the Greenwich quadrant is so intimately connected with the history of astronomy, the observations that have been made with it, and the deductions from those observations, are of such infinite importance to the science, that every circumstance relating to it cannot fail of being interesting. Now when it is considered that this instrument has been in constant use for upwards of half a century, and that the center error, from constant friction, would during this time have a regular tendency to increase, it will not appear at all surprising, if the former accuracy of this instrument should be somewhat impaired. With a view, therefore, of ascertaining more correctly the present state of an instrument on which so much depends, I have exhibited in one view the polar distances as determined by circular instruments alone; the respective co-latitudes being previously corrected by the method above mentioned, and I have compared the mean result with the Greenwich Catalogue, that the nature and amount of the deviations may be seen, and if it be judged necessary, corrected. I should add, that by some observations of the sun at the winter solstice in 1800, the difference between the Greenwich quadrant and the circle was 10 or 12″, the quadrant still giving the zenith distance too little.

General Description of the Instrument.

The annexed Plate represents the circle in its vertical position. It was originally made to be used likewise as an equatorial instrument, a circumstance I need not have mentioned, but as an apology for the slightness of its construction, which the artist who made it would not have recommended, had the instrument been intended for the vertical position only.

The declination circle, 30 inches in diameter, is composed of two complete circles; the conical radii of which are inserted at their bases in an axis about 12 inches long, leaving sufficient space between the limbs for a telescope $3\frac{1}{2}$ feet long, and an aperture of $2\frac{3}{4}$ inches, to pass between. The two circles are firmly united at their extreme borders by a great number of bars, which stand perpendicular between them; the whole of which will be readily understood by referring to the figure. The square frames, which appear as inscribed in the circle, were added to give additional firmness to the whole.

The circle is divided by fine lines into 5′ of a degree; and subdivided into single seconds by two micrometer microscopes, the principles and properties of which are now too well known to require any particular explanation.

At the time these observations were made, the microscopes were firmly fixed opposite to the horizontal diameter: but when I considered that, by continuing the observations, the error of division would never be diminished, I suggested to Mr. TROUGHTON the possibility of giving a circular motion to the microscopes, though I confess with very little hope, that the thing was really practicable in an instrument previously constructed on other principles. Mr. TROUGHTON approved of the idea, and executed it in a very ingenious manner. His talents, as an artist, are too well known and too highly appreciated, to stand in need of any praise from me; yet I should consider myself as deficient in justice, if I did not endeavour to call the attention of the reader to the skill and ingenuity, which have been employed not only in this very important alteration, but in every contrivance that is peculiar to the instrument, which is the object of our present consideration.

These microscopes can now revolve about 60° from their horizontal position; and it is easy to comprehend, that by this valuable improvement, all errors of division may be completely done away, without any of the manifest inconveniences of the French circle of repetition; which, though a very ingenious instrument, and admirably adapted to some particular operations, will, I think, never be adopted for general use in our observatories.

The plumb-line, a very material part of this instrument, is suspended from a small hook at the top of the tube at the left hand of the figure. It passes through an angle, in which it rests in the same manner as the pivot of a transit instrument does on its support. At the lower end of the tube which protects it, a smaller tube is fixed at right angles, which contains microscopic glasses so contrived, that the image of a luminous point, like the disc of a planet, is formed on the plumb-line and bisected by it. Great attention should be given to the accurate bisection of this transparent point by the plumb-line *at the moment of observation.* It is absolutely essential in instruments of this construction to consider the observation, as consisting in two bisections *at the same time:* the one of the star by the micrometer, the other of the plumb-line-point by the plumb-line. The least negligence in either of these bisections will render the observation unsuccessful.

The two strong pillars, which support the axis of the vertical circle, are firmly united at their bases to a cross bar; to which also the long vertical axis is affixed, and which may be considered as forming one piece with them. The stone pedestal is hollow, and contains a brass conical socket, firmly fastened to the stone, and reaching almost to the ground. This socket receives the vertical axis, and supports the whole weight of the moveable part of the instrument, which revolves on an obtuse point at the bottom; the upper part of this vertical axis is kept steady in a right angle, having two springs opposite the points of contact, which press it against its bearings, and it thus turns in these four points of contact with a very pleasant and steady motion.

The bar, in which the vertical axis is thus centered, is acted on by two adjusting screws in directions at right angles, and perfectly independent of each other. By these motions, the axis may be set as truly perpendicular, as by the usual method of the tripod with feet screws, which could not in this case have been employed.

The frame, to which this apparatus is attached, is fixed to the corners of the hexagonal stone, by the conical tubes; between which and the stone, the azimuth circle (which forms one piece with the vertical axis) turns freely. The azimuth circle of two feet diameter consists of eight conical tubes, inserted in the vertical axis; and which are united at their ends by the circular limb; this is divided and read off exactly in a similar manner to the other circle.

A level remains constantly suspended on the horizontal axis, which is verified in the same manner as in a transit instrument. There are forcing screws for this purpose, which pass through the bar on which the vertical columns stand, and these by pressing against the long axis produce a small change in the inclination of the upper part of the instrument, without altering the position of the azimuth circle or its axis.

The application of the plumb-line, as already described, is peculiar to the instruments made by Mr. Troughton: it regards the vertical axis rather than any other part, and is, in fact, exactly analogous to the usual verification of a zenith sector.

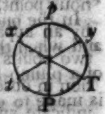
During the period in which I was engaged in making observations with circular instruments, I was led to consider the advantages and inconveniences of the usual method of adjusting them; and it appeared to me, that the essential part of their construction, which relates to their adjustment, was capable of being improved.

In order to render the nature of the improvement, which I wish to propose, more intelligible, I ought previously to remark, that there are, at present in use, two modes of adjusting these instruments, which are founded on different principles.

In the one, two points are taken on the limb of the circle; and when these are brought into a given position, by means of a plumb-line passing over them, the microscope or index is made to coincide with the zero point of the divisions: by this method, the error in collimation remains constant; and, if the adjustment is by any accident deranged, it can easily be rectified, and there will be no absolute necessity for frequently reversing the instrument; so that this method seems well adapted for large instruments, particularly if placed on stone piers. But it is liable to this defect, that the adjustment cannot be examined at the moment of observation; and if any change should take place in the general position of the frame work, the observation will be erroneous without the means of detection. It was probably to avoid this inconvenience, that

Mr. TROUGHTON, in most of his instruments, particularly if they were intended to move freely in azimuth, has preferred the other method.

In this case, the plumb-line is attached to one of the pillars which support the microscopes in the way above described; and it has no reference to any fixed points or divisions on the limb of the circle, but only insures a similarity of position in the index, for each position of the instrument; and, provided that the plumb-line apparatus was free from all danger of derangement, this would be sufficient. This verification may be rendered perhaps more intelligible, by considering that a circular instrument, in whatever manner its vertical axis be placed, indicates by a double observation, the angle which the object makes with the axis, round which the whole instrument has revolved in passing from one position to the other. For let Pp be the axis, Tx the telescope in one position; it is evident, that in turning the instrument half round, ty will then be the position of the telescope: Px being equal to Py. The arc xy, which the telescope passes through to regain its former position, is the quantity really given by the instrument; and if the axis Pp be vertical, half this quantity is the true zenith distance of the object. Now the intention of Mr. TROUGHTON's verification is to insure a vertical position to the axis Pp.



For instruments which rest on moveable pillars, and turn freely in azimuth, this method is much to be preferred; but it is not without a considerable defect: for, if by any derangement in the plumb-line apparatus, the error in collimation be changed, it cannot be restored with certainty to its former position; so that sometimes a very valuable series of observations may be lost, for want of a corresponding one to compare with it. The mode which I propose to adopt to remedy these inconveniences, will enable us to combine all the advantages of the two methods above described: it is extremely simple in its principle, and easy of execution, for it merely consists in uniting on the same plumb-line the two principles already explained.

Two very fine holes should be made in the farther limb of the circle, and two lenses firmly fixed opposite to them, in the other, which should each form an optical image of its corresponding dot or hole, in the tube through which the plumb-line passes.* It will be best, if these dots are made exactly in a diameter, as they may then be used in two positions. Beneath these should be formed the image of a luminous point, according to Mr. Troughton's present method, by an apparatus attached to the plumb-line tube; when the two points on the circle move away, by the necessary operation in observing, the lower point will remain stationary, and indicate any change of position in the whole instrument, if such should accidentally take place, and which by the other method alone would have passed unnoticed.

The contrivance above described was executed for me at my request by Mr. Troughton, and is represented in the Plate; but by some accident a part of the apparatus was broken in putting it together, so that I never was able to use it. As each apparatus for this adjustment is quite independent of the other, no possible inconvenience can attend their application, as either may be employed alone, at the option of the observer. But as any verification requiring many bisections is objectionable, I would in general certainly prefer Mr. TROUGHTON's method, and only have recourse to the other, when there was reason to suspect that some alteration had taken place to render it necessary.

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* As these transparent dots are intended to be bisected by the plumb-line, they must be capable of the necessary adjustments, both for distinct vision, and for placing them in an exact diameter.

It may be found more convenient in practice to arrange the whole apparatus in sliding tubes, but in whatever way the contrivance be executed, the points should ultimately be fixed as firmly as the divisions of the instrument.

One more circumstance respecting the instrument remains to be noticed: when the divisions were first examined by opposite readings, 1″,25 was the greatest possible error which was to be apprehended, and 0″,7 the mean error; but in its journey it seemed to have suffered some very small derangement in its form: this was discernible both from examining the opposite readings; and by deducing the error of collimation by zenith stars, and comparing it with that found by an horizontal object, there was constantly perceived a difference of 3″ between the error of collimation deduced from γ Draconis and by an horizontal object; and this quantity was very uniformly distributed through the intermediate arc. In what particular manner the observations would be affected by this derangement I will not venture to decide, but I think it most likely that it has only rendered the instrument rather less accurate than it was originally, as is above stated. I have before observed the great advantage the circle possesses of showing the amount of its own errors. These may be determined with great certainty by examining the errors of collimation as deduced from different stars. This method is founded upon the supposition that half the difference of the two extreme quantities is the greatest error of division, which has in this case influenced each result in an opposite direction. For instance, let us suppose the errors of division never to exceed 2″, but occasionally to amount to that quantity, on several parts of the circle; it will then sometimes occur that each index will give 2″ too much in one position of the instrument, and 2″ too little in the other; there will then appear a difference of 4″ in the error of collimation; but the observations in these extreme cases will not on that account be the less to be depended on; on the contrary, the probability is in favour of their superior accuracy.

Nor, on the other hand, will those observations which give the mean error of collimation deserve greater confidence than the rest, since it is evident that some of them may be, and most probably are, affected with the greatest possible error; for we suppose the most erroneous observation to arise from the greatest error of division occurring on each of the four arcs in the same sense, that is all *plus* or all *minus*; nevertheless, the observation thus erroneous, will give the mean error of collimation.

By an attentive consideration of these circumstances, corrections might perhaps be obtained which would somewhat diminish the probability of error. But it is to the principle of the revolving microscopes, that in the future construction of instruments we should look for perfection. In the French circle of repetition, too great a sacrifice is made to the supposed advantage of reading off a great number of observations at once. Our best instruments are too well constructed to stand in need of this contrivance, as the divisions on a two-feet circle are read off with precision to a single second.

The errors of simple division alone are those which continued observations have no tendency to diminish; these, by making the microscopes revolve, may be completely done away. An instrument thus constructed would be well adapted to detect small motions in the fixed stars which hitherto have escaped notice, or such as are but imperfectly known; for we cannot reasonably conclude that what is termed the proper motion of a star is so uniform and constant, that being once determined, it will remain always the same.

In the following observations, the larger number expresses the altitude, + 90°, and the smaller number the zenith distance; the thermometer was attached to the telescope.

In reducing the observations of 1801, the proper motions are allowed for, according to the latest tables of Dr. MASKELYNE.

γ Pegasi.

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.48,0.
1800	° ′ ″	Inches.	°	″	° ′ ″	° ′ ″
Nov. 3	142.50.27,5	29,2	48	42,5	37. 9.30,1	75.55.36,7
7	37. 9.27,8	29,2	51	42,5		
11	37. 9.26,9	29,6	48	43,3		
17	142.50.50	29,7	47	43,7	37. 9.28,4	75.55.35,0
18	37. 9.46,7	30,1	44	44,5		
19	37. 9.47	30,2	41	45	37. 9.31,3	75.55.38,0
20	142.50.44,5	30,3	41	45,1		
25	142.50.24,6	29,0	51	42,4	37. 9.31,7	75.55.38,3
26	37. 9.28	29,5	44	43,7		
27	142.50.26,8	29,6	42,5	43,9	37. 9.32,3	75.55.38,9
29	37. 9.31,5	30,0	42	44,5		
30	37. 9.28,2	30,0	45	44,2	37. 9.29,4	75.55.36,0
Dec. 6	142.50.29,5	29,2	40	43,7		
7	142.50.26,5	29,4	40	44,0	37. 9.30,2	75.55.37,0
8	37. 9.27	29,5	38	44,4		
16	37. 9. 2,1	30,0	44	44,3	37. 9.30,1	75.55.36,0
24	142.49.54,5	29,3	48	43,0		
25	37. 8.54,7	29,4	47	43,2		
31	37. 9. 0,2	29,9	39	44,7	37. 9.32,3	75.55.37,5
1801 Jan. 1	37. 9. 0	29,7	43	44,0		
3	142.49.55,9	29,7	47	43,6		
Mean polar distance for Jan. 1800 - -						75.55.37,0

α Arietis.

1800 Dec. 24	151.16.12,7	29,4	46	31,3	28.43.12,9	67.29.22,0
25	28.42.38,5	29,4	46	31,3		
26	28.42.37,2	29,4	43	31,5	28.43.11,7	67.29.20,8
27	28.42.38,2	29,6	43	31,7		
1801 Jan. 1	28.42.38,2	29,7	45	31,7		
3	151.16.14,6	29,8	44	31,9		
7	28.43.33,0	30,0	45	32,0	28.43.11,3	67.29.20,0
10	28 43.32,0	30,1	47	32,0		
14	28.43.30,0	29,9	45	31,9		
16	151.17. 9,0	29,6	46	31,5		
17	151.17. 8,7	29,6	46	31,5		
Mean polar distance for Jan. 1800 - - -						67.29.20,6

α Ceti.

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co latitude 38.45.42,0
1801	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Jan. 14	47.56.29,6	29,9	45	1.4,4	47.56. 8,4	86.42. 9,4
16	132. 4.13,2	29,7	45	1.3,8		
17	132. 4.12,3	29,6	45	1.3,5		
24	132. 3.47,9	29,8	35	1.5,8	47.56.10,7	86.42.11,2
25	47.56. 9,3	29,8	35	1.5,8		
	Mean	-	-	-	- -	86.42.10,3

Aldebaran.

1800						
Dec. 24	144.51. 8,2	29,4	46	40,2	35. 8.17,5	73.54.17,5
1801						
Jan. 1	35. 7.43,3	29,7	43	41,0		
20	144.51.43,2	29,9	48	40,8	35. 8.15,5	73.54.14,5
24	35. 8.14,3	29,8	35	41,8		
25	35. 8.14,8	29,8	35	41,8	35. 8.16,0	73.54.14,8
29	144.51.42,6	29,7	45	40,7		
Feb. 6	144.51.41,3	30,0	49	40,7	35. 8.17,0	73.54.15,5
7	35. 8.15,4	30,1	45	41,2		
	Mean polar distance Jan. 1800			- -	-	73.54.15,5

Capella.

1800						
Dec. 24	174.32. 3,5	29,4	46	5,5	5.27.19,2	44.13.19,1
1801						
Jan. 1	5.26.42,1	29,7	43	5,6		
14	5.27.31,1	29,9	45	5,6	5.27.14,8	44.13.16,9
17	174.33. 1,5	29,6	45	5,5		
20	174.32.39,4	29,9	48	5,5	5.27.14,8	44.13.17,6
24	5.27. 9,0	29,8	35	5,8		
27	5.27. 9,7	29,7	41	5,6	5.27.14,9	44 13.18,3
29	174.32.39,9	29,7	46	5,6		
Feb. 23	5.27. 3,8	29,2	46	5,5	5 27.12,8	44.13.17,7
24	174.32.38,2	29,6	42	5,6		

Capella (continued.)

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.43,0.
	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
26	5.27. 3,6	29,9	45	5,6	5.27.12,6	44.13.17,7
Mar. 4	174.32.38,4	30,3	51	5,6		
7	174.32.37,9	30,2	51	5,6	5.27.14,0	44.13.19,8
8	174.32.37,7	30,0	46	5,6		
12	174.32.38,0	29,4	45	5,5		
23	5.27. 6,0	29,3	48	5,5		
31	5.27.27,5	30,2	55	5,5	5.27.14,9	44.13.19,5
April 1	174.32.57,7	30,2	59	5,5		
	Mean -	-	-	- -	- - -	44.13.18,5

Rigel.

1801						
Jan. 14	59.41. 6,0	29,9	45	1.39,2	59.40.45,3	98.26.36,5
17	120.19.35,5	29,6	45	1.38,2		
20	120.19 11,5	29,9	48	1.38,5	59.40.48,0	98.26 38,5
24	59 40 47,4	29,8	35	1.41,2		
27	59.40.46,0	29,7	41	1.39,5	59.40.47,5	98.26.37,5
29	120.19.11,2	29,7	46	1.38,3		
Feb. 6	120.19.13,7	30,0	50	1.38,3	59.40.46,0	98.26.35,0
7	59.40.45,5	30,1	46	1.39,5		
23	120.19. 7,4	29,2	42	1.37,6	59.40.49,5	98.26.37,5
26	59.40.46,5	29,9	45	1.39,0		
Mar. 3	120.19. 6,2	30,3	53	1.38,8	59.40.48,0	98.26.35,5
4	120.19. 7,7	30,3	51	1.39,3		
7	120.19. 3,5	30,2	46	1.39,0		
8	120.19. 6,5	30,0	45	1.38,6		
12	120.19. 5,0	29,4	48	1.37,0		
23	59 40 42,0	29,3	45	1.37,3		
31	59.41. 2,0	30,2	55	1.37,8	59.40.48,4	98.26.35,9
April 1	120.19.25,2	30,2	59	1.37,0		
2	59.41. 5,8	30,1	63	1.35,6	59.40.50,0	98.26.37,6
3	120.19.26,0	30,0	64	1.35,0		
	Mean -	-	-	- -	- -	98.26.36,5

β *Tauri.*

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38 45.48,0.
1800	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Dec. 24	157.10.53,2	29,4	46	24,0	22.48.34,8	61.34.32,5
1801						
Jan. 1	22.48. 2,9	29,7	43	24,4		
14	22.48.55,0	29,9	45	24,4	22.48.35,0	61.34.32,5
17	157.11.45,0	29,6	45	24,2		
20	157.11.21,2	29,9	48	24,3	22.48.36,6	61.34.34,0
24	22.48.34,5	29,8	35	25,0		
25	22,48.35,0	29,8	35	25,0	22.48.36,5	61.34 34,0
27	22.48.34,6	29,7	41	24,6		
29	157.11.21,8	29,7	46	24,2		
Feb. 6	157.11.22,8	30,0	50	24,2	22.48.35,1	61.34.33,0
7	22.48.33,0	30,1	46	24,5		
23	157.11.18,3	29,2	42	24,0	22.48.35,2	61.34.33,5
26	22.48.29,0	29,9	45	24,5		
Mar. 3	157.11.19,2	30,3	53	24,3	22.48.35,1	61.34.33,7
4	157.11.21,1	30,3	51	24,4		
7	157.11.17,5	30,2	46	24,6		
8	157.11.17,2	30,0	45	24,6		
12	157.11.19,3	29,4	48	23,9		
23	22.48.28,8	29,3	45	23,8		
31	22.48.50,6	30,2	55	24,1	22.48.35,9	61.34.34,0
April 1	157.11.38,8	30,2	59	23,9		
Mean	-	-	-	-	-	61.34.33,7

α *Orionis.*

1801			°			
Jan. 14	43.52.59,5	29,9	45	56,0	43.52.38,8	82.38.30,5
17	136. 7.42,0	29,6	45	55,4		
20	136. 7.16,5	29,9	48	55,5	43.52.41,6	82.38.31,0
24	43.52.39,7	29,8	35	57,2		
27	43.52.39,2	29,7	41	56,2	43.52.40,5	82.38.30,5
29	136. 7.18,2	29,7	45	55,7		
Feb. 6	43.52.39,7	30,0	50	55,4	43.52 41,9	82.38.31,4
7	136. 7.16,0	30,1	46	56,2		
Mean	-	-	-	-	-	82.38.31

Sirius.

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.48,0.
1801	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Jan. 25	67.41.23,0	29,8	35	2.24,1	67.41.22,0	106.27. 1,8
29	112.18.39,2	29,8	44	2.22,0		
Feb. 20	67.41.24,0	29,5	44	2.20,5	67.41.26,0	106.27. 3,0
22	112.18 32,2	29,2	43	2.19,5		
27	112.18.31,5	29,9	45	2.21,0	67.41.25,5	106.27. 1,5
Mar. 4	67.41.22,5	30,3	49	2.21,3		
Mean	-	-	-	-	- -	106.27. 2,1

Castor.

1801						
Feb. 26	18.55.22,0	29,9	45	19,5	18.55.30,2	57.41.14,8
27	18.55.21,8	29,9	45	19,5		
Mar. 4	161. 4 24,5	30,3	50	19,7		
7	161. 4 20,5	30,3	45	19,8		
8	161. 4 22,9	30,0	44	19,6	18.55.27,2	57.41.12,6
15	18.55.17,2	29,6	42	19,5		
April 2	18.55.41,3	30,1	56	19,1	18.55.27,1	57.41.13,5
3	161. 4.47,2	30,0	58	19,0		
17	18.55.47,3	29,8	50	19,3	18.55.29,1	57.41.15,5
18	161. 4.49,1	30,0	50	19,4		
Mean	-	-	-	-	- -	57.41.14,0

Procyon.

1801						
Feb. 20	45.30.42,9	29,5	45	58,4	45.30.45,7	84.16.22,1
22	134.29.11,4	29,2	43	58,1		
24	45.30.37,8	29,6	40	59,3	45.30.45,1	84.16.21,2
26	45.30 44,2	29,9	45	59,2		
27	45.30.41,2	29,9	45	59,2		
Mar. 4	134 29.12,2	30,3	50	59,3		
7	134 29 10,0	30,3	45	60,0		
8	134.29.10,0	30,0	44	59,5		
15	45.30 38,5	29,6	42	59,0		

Procyon. (continued.)

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.43,0.
1801	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
April 2	45.31. 1,0	30,1	56	58,0	45.30.45,0	84.16.21,1
3	134.29.31,0	30,0	58	57,5		
17	45.31. 7,8	29,8	50	58,3	45.30.46,0	84.16.21,6
18	134.29.35,8	30,0	50	58,7		
19	134.29.38,0	30,0	52	58,5		
	Mean	-	-	-	-	84.16.21,5

Pollux.

1801						
Feb. 24	22.44.24,5	29,6	40	24,5	22.44.31,5	61.30.14,0
26	22.44.27,4	29,9	45	24,7		
27	22.44.27,0	29,9	45	24,7		
Mar. 4	137.15.21,1	30,3	50	24,4		
7	137.15.22,7	30,3	45	24,8		
8	137.15.23,1	30,0	44	24,6		
15	22.44.23,0	29,6	42	24,3		
April 2	22.44.44,5	30,1	56	24,0	22.44.29,2	61.30.12,7
3	157.15.46,2	30,0	58	23,8		
	Mean	-	-	-	-	61.30.13,7

Regulus.

1800						
Oct. 31	38.17.54,6	30,0	45	46,12	38.17.57,3	77. 3.34,0
Nov. 5	141.42.00	29,5	44	45,48		

β Leonis.

1800						
Nov. 13	35.32.59,9	29,8	50	41,7	35.33. 2,6	74.18.31,5
14	144.26.54,6	29,4	50	41,7		
17	35.33.15,2	29,9	43	42,5	35.33. 1,8	74.18.29,5
18	144.27.11,7	30,1	38	42,8		
1801						
Nov. 8	144.27.22,0	30,0	42	42,0	35.33.27,0	74.18.35,5
13	35.33.15,8	30,0	44	41,8		
	Mean	-	-	-	-	74.18.32,5

Spica Virginis.

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitue 38.45.48,0.
1800	° ′ ″	Inches	°	′ ″	° ′ ″	° ′ ″
Nov. 17	61.21.31,5	30,0	45	1.46,5	61.21.11,3	100. 6.43,3
18	61.21.29,7	30,1	40	1. 4,8		
19	118.39. 8,0	30,3	40	1.48,5		
25	118.38.48,6	29,3	44	1.44,5	61.21.12,3	100. 6.42,9
27	118.38.45,8	29,7	39	1.47,2		
Dec. 1	61.21.13,3	29,6	44	1.45,2		
2	61.21.10,2	29,4	43	1.45,0		
7	118.38.44,5	29,3	38	1.46,0	61.21.13,3	100. 6.42,5
9	61.21.12,1	29,6	38	1.46,8		
10	61.21.11,3	29,6	41	1.46,1		
12	61.21.10,2	29,8	42	1.46,7		
Mean	-	-	-	-	-	100. 6.43,0

Arcturus.

1800						
Nov. 16	148.59.34,1	29,6	48	34,3	31.00.41,8	69.46. 8,5
17	31.00.57,6	30,0	46	35,1		
18	31.00.55,8	30,2	42	35,6	31.00.42,3	69.46. 8,2
19	148.59.31,1	30,3	42	34,6		
25	148.59. 7,9	29,3	45	35,0	31.00.46,6	69.46.10,7
26	31.00.41,2	29,6	41	35,0		
27	148.59. 8,5	29,8	39	35,2	31.00.46,5	69.46.10,5
28	31.00.41,6	29,8	42	35,2		
Dec. 1	31.00.42,7	29,6	44	34,7	31.00.45,0	69.46. 8,0
2	148.59.12,7	29,4	44	34,5		
6	148.59. 8,2	29,3	38	35,0	31.00.46,7	69.46. 8,5
7	31.00.40,8	29,6	40	35,0		
9	31.00.42,4	29,6	38	35,1		
Mean	-	-	-	-	-	69.46. 9,0
Corrected for the proper motion of the star					-	69.46. 7,5

α *Coronæ.*

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.48,0.
1800	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Nov. 5	23.50.37,0	29,6	49	25,2	23.50.42,2	62.36.13,0
6	23.50.39,4	29,3	51	24,9		
13	156. 9.13,9	29,7	48	25,4		
17	156. 9.34,8	29,6	49	25,2	23.50.42,6	62.36.11,5
19	23.50.59,0	30,2	44	26,0		
20	156. 9.32,8	30,3	43,5	26,1		
25	156. 9. 9,7	29,4	46	25,3	23.50.46,5	62.36.13,5
26	23.50.41,8	29,6	42	25,7		
27	156. 9. 7,6	29,8	41	25,9	23.50.47,7	62.36.14,4
28	23.50.43,1	29,8	44	25,7		
29	23.50.43,7	30,0	44	25,8	23.50.47,9	62.36.13,4
Dec. 2	156. 9. 7,9	29,4	44	25,4		
7	23.50.44,4	29,5	41	25,7	23.50.49,1	62.36.13,0
9	23.50.44,9	29,6	39	25,7		
26	23.50.23,3	29,6	41	25,6	23.50.56,6	62.36.14,0
30	23.50.24,0	29,5	35	25,8		
1801						
Jan. 3	156. 8.30,4	29,7	44	25,6		
Mean	-	-	-	-	-	62.36.13,0

α *Serpentis.*

1800						
Dec. 2	135.49.25,0	29,4	24,4	55,8	44.10.34,0	82.56. 2,0
7	44.10.34,5	29,5	40	56,5		
9	44.10.34,3	29,6	39	56,8		

α *Ophiuchi.*

1800						
Nov. 5	38.31.10,4	29,6	49	45,6	38.31.13,5	77.16.52,2
13	141.28.44,3	29,7	48	45,7		
14	141.28.42,6	29,8	51	45,6		
19	38.31.31,4	30,2	44	46,9	38.31.21,1	77.16.54,5
20	141.28.48,9	30,3	44	47,0		

α *Ophiuchi.* (*continued.*)

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.48,0.
1800	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Nov. 26	38.31.13,2	29,4	46	45,4	38.31.16,7	77.16.53,3
27	141.29.39,9	29,6	45	45,8		
Dec. 25	38.30.51,6	29,4	44	45,6	38.31.24,0	77.16.53,6
26	38.30.51,5	29,6	43	46,0		
1801						
Jan. 3	141.28. 3,3	29,7	46	45,9		
	Mean	-	-	-	-	77.16.53,5

α *Lyræ.*

1800						
Oct. 31	12.37.42,6	29,9	50	12,7	12.37.46,5	51.23.36,5
Nov. 3	167.22. 9,6	29,2	51	12,6		
17	167.22.28,2	29,6	49	12,8	12.37.46,8	51.23.34,2
18	12.38. 0,8	30,0	45	13,0		
20	167.22.26,1	30,3	43	13,2		
25	167.22. 2,7	29,0	56	12,3	12.37.51,0	51.23.36,7
26	12.37.44,5	29,4	46	12,8		
28	167.22. 4,5	29,8	41	13,1	12.37.48,7	51.23.33,8
29	12.37.42,0	29,9	43	13,1		
30	12.37.45,0	30,0	46	13,0	12.37.52,6	51.23.36,8
Dec. 2	12.37.47,9	29,6	44	12,9		
3	167.22. 2,0	29,4	45	12,8		
8	167.22. 0,1	29,5	42	12,9		
24	167.21.25,7	29,3	50	12,6	12.37.59,0	51.23.35,0
25	12.37.23,7	29,4	48	12,7		
1801						
Jan. 2	167.21.26,4	29,7	50	12,8		
3	167.21.23,3	29,7	46	12,9		
14	12.38.22,7	29,9	48	13,0	12.38. 1,8	51.23.34,0
15	167.22.20,0	29,7	48	13,0		
17	167.22.18,3	29,6	45	12,9		
21	12.38. 3,0	29,6	48	12,8	12.38. 8,0	51.23.37,8
22	12.38. 3,0	29,4	40	13,0		
23	167.21.48,0	29,6	36	13,2		
24	167.21.46,0	29,6	36	13,2		

α *Lyræ. (continued.)*

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.43,0.
1801	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Feb. 4	167.21.45,7	29,9	51	12,8	12.38.11,8	51.23.37,4
5	167.21.43,7	29,8	50	12,8		
6	167 21.44,0	30,1	45	13,0		
9	12.38. 6,1	30,1	40	13,1		
13	12.38. 8,0	29,6	31	13,3		
22	167.21.38,1	29,2	40	13,0	12.38.13,0	51.23.35,8
23	12.38. 4,0	29,3	40	13,3		
Nov. 9	12.37.32,4	30,0	50	12,9	12.37.43,6	51.23.35,5
10	12.37.32,3	29,0	51	12,8		
14	167.22. 5,1	30,0	49	12,9		
21	12.37.32,5	29,4	45	12,8	12.37.49,3	51.23.35,3
30	12.37.34,2	28,9	40	12,7		
Dec. 10	12.37.37,7	29,3	46	12,7		
13	167.21.56,5	29,6	46	13,0		
14	167.21.56,0	29,6	38	13,0		
Mean		-	-	-	-	51.23.36,0

α *Aquilæ.*

1800						
Nov. 18	42.53.14,0	30,0	45	54,0	42.53.00,0	81.38.49,0
20	137. 7.13,9	30,3	43	54,7		
26	42.53. 1,2	29,4	44	53,4	42.53. 3,9	81.38.52,0
28	137. 6.53,3	29,6	42	53,9		
29	42.52.57,5	29,9	44	54,2	42.53. 2,6	81.38.50,2
Dec. 3	137. 6.52,3	29,4	45	53,1		
24	137. 6.17,9	29,3	48	52,7	42.53. 8,5	81.38.52,7
31	42.52.35,0	29,7	39	54,5		
1801						
Jan. 3	137. 6.19,6	29,7	50	52,9		
4	137. 6.19,2	29,7	48	53,1		
14	42.53.29,1	29,9	48	53,6	42.53. 9,5	81.38.50,7
15	137. 7.10,0	29,7	45	56,6		
22	42.53.10,8	29,4	40	53,8	42.53.14,0	81.38.53,0
Feb. 6	137. 6.42,7	31,0	45	54,3		
Mean		-	-	-	-	81.38.51,5

α ♑.

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800: The Co-latitude 38.45.48,0.
1801	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Nov. 18	64.23.39,0	30,0	45	2. 1,5	64.23.24,5	103. 9. 8,6
19	64.23.40,8	30,1	44	2. 2,0		
20	115.36.51,8	30,3	42,5	2. 3,2		
26	64.23.19,2	29,5	45	1.59,2	64.23.22,5	103. 9. 6,6
28	115.36.34,0	29,8	42	2. 1,4		
Mean	-	-	-	-	-	103. 9. 7,6

α *Cygni.*

1800						
Nov. 17	173.20.38,8	29,6	49	6,7	6.39.32,2	45.25.34,1
18	6.39.43,3	30,0	45	6,8		
19	6.39.46,1	30,2	44	6,8	6.39.33,7	45.25.35,3
20	173.20.38,6	30,3	42	6,9		
25	173.20.16,0	29,0	53	6,5	6.39.37,2	45.25.37,8
26	6.39.30,5	29,4	45	6,7		
28	173.20.18,4	29,8	41	6,8	6.39.35,0	45.25.35,5
29	6.39.28,3	29,9	43	6,8		
30	6.39 29,4	30,0	46	6,8	6.39.35,8	45.25.36,0
Dec. 2	173.20.17,8	29,6	44	6,7		
3	173.20.17,8	29,4	44	6,7	6.39.35,0	45.25.35,0
8	6.39.28,3	29,5	42	6,8		
16	6.39. 5,0	29,6	38	6,8	6.39.43,7	45.25.36,8
25	6.39. 5,2	29,4	48	6,7		
31	6.39. 6,3	29,7	48	6,7		
1801						
Jan. 2	173.19.39,7	29,9	43	6,8		
3	173.19.39,8	29,7	50	6,7		
22	6.39.47,4	29,6	45	6,7	6.39.52,4	45.25.39,5
23	6.39.47,0	29,4	40	6,8		
25	173.20. 2,6	29,6	36	6,9		
29	173.20. 2,0	29,8	46	6,7		
Feb. 19	6.39.54,2	29,5	46	6,7	6.39.59,9	45.25.40,2
22	173.19.54.3	29,2	42	6,7		
April 2	6.40.17,2	30,0	54	6,7	6.40. 5,2	45.25.39,0
4	173.20. 6,8	29,8	43	6,7		

α Cygni. (continued.)

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.42,0.
1801	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
April 5	6.40.20,7	29,8	45	6,7	6.40. 6,0	45.25.39,7
7	173.20. 8,8	29,6	45	6,7		
8	173.20.10,2	29,6	40	6,8	6.40. 4,1	45.25.37,7
10	6.40.18,3	29,5	42	6,8		
11	6.40.22,8	29,6	40	6,8	6.40. 6,3	45.25.39,7
12	6.40.22,5	30,2	35	7,0		
13	173.20. 9,6	30,2	39	6,9		
14	173.20.10,7	30,0	42	6,8		
Nov. 8	173.20.27,2	29,8	45	6,8	6.39.22,3	45.25.37,6
9	6.39.11,8	30,0	48	6,8		
13	6.39.10,0	29,9	48	6,8	6.39.21,3	45.25.36,3
14	173.20.27,4	30,0	48	6,8		
18	173.20.24,2	29,5	43	6,7	6.39.22,3	45.25.36,6
19	6.39. 8,8	29,6	42	6,7		
26	173.20.22,5	29,4	45	6,7	6.39.22,7	45.25.36,0
30	6.39. 9,7	29,0	40	6,7		
Dec. 1	6.39. 9,7	29,0	40	6,7	6.39.23,0	45.25.35,8
2	6.39. 9,2	29,0	40	6,7		
3	173.20.23,2	29,6	40	6,8		
7	173.20.24,7	29,4	40	6,8		
9	173.20.23,2	28,7	47	6,5	6.39.24,0	45.25.35,6
11	6.39.10,9	29,6	45	6,7		
13	173.20.21,2	29,6	38	6,8	6.39.26,0	45.25.36,2
14	173.20.22,7	29,6	38	6,8		
16	6.39.14,5	29,3	35	6,8		
17	6.39.14,0	29,5	35	6,8		
	Mean	-	-	-	- -	45.25.37,0

α *Aquarii.*

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.45.42,0.
1800	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Nov. 17	137.29. 6,7	29,7	46	1.14,8	52.31. 8,7	91.17. 4,3
18	52.31.24,1	30,1	45	1.16,5		
19	52.31.26,7	30,2	41	1.17,2	52.31.11,0	91.17. 6,4
20	137.29. 4,8	30,3	41	1.17,5		
26	52.31. 3,9	29,5	44	1.14,9	52.31. 7,7	91.17. 2,7
28	137.28.48,4	29,8	41	1.16,3		
29	52.31. 6,1	29,9	43	1.16,1	52.31.10,2	91.17. 5,0
Dec. 2	137.28.45,7	29,5	44	1.15,0		
3	137.28.47,1	29,4	42	1.15,0	52.31.10,0	91.17. 4,6
8	52.31. 7,3	29,5	40	1.15,7		
Mean	-	-	-	-	-	91.17. 4,6

α *Pegasi.*

1800						
Nov. 17	142.54.25,9	29,7	46	43,5	37. 5.53,0	75.51.57,2
18	37. 6.11,9	30,1	44	44,4		
19	37. 6.10,0	30,2	40	45,0	37. 5.54,1	75.51.58,0
20	142.54.21,8	30,3	40	45,2		
26	37. 5.49,8	29,5	44	43,5	37. 5.54,8	75.51.58,7
27	142.54.00,1	29,6	42	43,9		
Dec. 24	142.53.30,0	29,3	47	43,0	37. 5.56,8	75.51.58,7
25	37. 5.23,7	29,4	47	43,0		
26	37. 5.25,0	29,4	43	43,4	37. 5.56,0	75.51.57,2
31	37. 5.24,0	29,8	38	44,4		
Jan. 1	37. 5.22,8	29,7	45	43,6		
3	142.53.32,1	29,7	47	43,4		
Mean	-	-	-	-	-	75.51.58,0

α *Andromedæ.*

Day of the Month.	Observations uncorrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38.46.10,0.
	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
1800 Nov. 17	156.45.37,2	29.75	47	24,8	23.14.38,4	62.00.48,4
18	23.14.54,0	30, 1	44	25,2		
19	23.14.58,2	30, 2	41	25,5	23.14.40,6	62.00.49,6
20	156.45.37,0	30, 3	41	25,5		
25	156.45.13,7	29, 0	51	24,0	23.14.41,0	62.00.51,2
26	23.14.36,8	29, 5	44	24,6		
27	156.45.14,2	29, 6	42,5	25,0	23.14.40,3	62.00.50,7
29	23.14.35,5	30, 0	42	25,3		
30	23.14.38,3	30, 0	45	25,0	23.14.39,0	62.00.49,4
Dec. 6	156.45.20,2	29, 2	40	24,8		
7	156.45.18,5	29, 4	39	25,0	23.14.38,3	62.00.48,5
8	23.14.35,0	29, 5	38	25,1		
16	23.14.11,5	30, 0	44	25,0	23.14.41,7	62.00.51,4
24	156.44.45,1	29, 3	48	24,4		
25	23.14. 5,5	29, 4	47	24,5		
31	23.14. 8,3	29, 9	39	25,3	23.14.40,7	62.00.50,0
1801 Jan. 1	23.14. 8,6	29, 7	43	24,9		
3	156.44.47,0	29, 5	47	24,7		
18	156.45.14,6	29, 9	46	25,1	23.14.44,0	62.00.50,7
22	23.14.42,5	29, 6	44	24,9		
	Mean	-	-	-	-	62.00.50,0

Polaris.

Day of the Month.	Zenith Distance corrected for Refraction.	Reduced to January, 1800.
1800	° ′ ″	° ′ ″
Nov. 2	37.00.30,3	37.00.3,2
4	37.00.30,8	37.00.3,0
7	37.00.31,3	37.00.2,4
11	37.00.32,7	37.00.2,7
17	37.00.36,0	37.00.4,2
18	37.00.36,3	37.00.4,3
19	37.00.35,7	37.00.3,4
20	37.00.36,3	37.00.3,8
21	37.00.37,6	37.00.4,8
25	37.00.40,1	37.00.5,8
27	37.00.39,5	37.00.4,9
29	37.00.40,3	37.00.5,2
30	37.00.40,1	37.00.4,8
Dec. 23	37.00.44,2	37.00.5,2
1801		
Jan. 1	37.00.44,3	37.00.4,6
21	37.00.44,2	37.00.5,0
24	37.00.44,7	37.00.5,8
25	37.00.44,3	37.00.5,2
Feb. 6	37.00.43,6	37.00.5,7
25	37.00 40,8	37.00.6,2
Mar. 2	37.00 39,3	37.00.5,8
25	37.00.33,4	37.00.5,6
31	37.00.30,6	37.00.4,2
April 1	37.00.30,9	37.00.4,8
2	37.00.29,7	37.00.3,9
3	37.00.29,9	37.00.4,5
4	37.00.29,2	37.00.4,4
5	37.00.28,4	37.00.3,9
13	37.00.28,2	37.00.5,5
June 11	37.00.15,0	37.00.3,5

N. B. These observations of the polar star were all made by reversing the instrument several times, before and after the star's passage over the meridian, allowing for the small change in altitude, according to the French tables constructed for that purpose.

Polaris. (continued.)

Day of the Month.	Zenith Distance corrected for Refraction.	Reduced to January, 1800.
1801	° ′ ″	° ′ ″
June 13	37.00.16,5	37.00.5,0
21	37.00.17,0	37.00.5,4
Nov. 26	37. 1. 2,0	37.00.6,0
Dec. 7 12	37. 1. 5,5	37.00.6,0
13 14	37. 1. 6,2	37.00.6,5
16 17 18 19	37. 1. 5,5	37.00.5,2

Polaris, S. P.

1800		
Oct. 31	40.30.52,0	40.31.18,6
Nov. 3	40.30.54,0	40.31.18,1
4	40.30.51,2	40.31.19,2
13	40.30.48,0	40.31.18,8
17	40.30.46,8	40.31.18,8
18	40.30.45,9	40.31.18,1
19	40.30.46,5	40.31.19,0
26	40.30.44,6	40.31.19,1
27	40.30.43,2	40.31.18,5
28	40.30.44,0	40.31.19,0
Dec. 10	40.30.41,8	40.31.19,0
1801		
June 8	40.31. 4,0	40.31.16,5

Polaris, S. P. (continued.)

Day of the Month.	Zenith Distance corrected for Refraction.	Reduced to January, 1800.
1801	° ′ ″	° ′ ″
June 4	40.31. 5,7	40.31.17,6
5	40.31. 3,6	40.31.15,6
6	40.31. 5,7	40.31.17,5
8	40.31. 4,0	40.31.15,8
9	40.31. 3,5	40.31.15,2
10	40.31. 6,5	40.31.18,1
Nov. 8	40.30.27,7	40.31.18,7
13	40.30.25,8	40.31.18,2
18	40.30.26,0	40.31.20,0
19	40.30.25,9	40.31.20,1
20	40.30.25,1	40.31.19,5
25	40.30.23,2	40.31.19,0
27	40.30.23,4	40.31.19,8
Dec. 2	40.30.22,7	40.31.20,1
5	40.30.21,9	40.31.20,0

β Ursæ.

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Reduced to January, 1800.
1800	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Dec. 24	23.42.55,2	29,4	44	25,2	23.43.31,4	23.44. 6,0
25	156.15.52,4	29,4	43	25,2		
26	156.15.52,5	29,6	41	25,5		
1801						
Jan. 1	23.42.55,7	29,9	43	25,7		
July 20	23.43.48,7	30,0	72	25,0	23.43.57,8	23.44. 8,3
21	156.15.53,1	30,0	70	25,0		

β *Ursæ. (continued.)*

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Reduced to January, 1800.
1801	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Dec. 2	23.43.12,0	29,4	40	25,4	23.43.22,9	23.44. 8,8
6	23.43.11,[illegible]	29,4	40	25,4		
7	23.43.10,1	29,4	40	25,4		
9	156.16.27,1	29,3	46	25,0		
11	156.16.26,7	29,6	38	25,3		
12	23.43. 7,5	29,6	38	25,8	23.43.19,7	23.44. 8,2
13	23.43. 8,5	29,6	34	26,0		
18	156.16.28,5	30,0	32	26,5		
	Mean	-	-	-	-	23.44. 7,8

β *Ursæ, S. P.*

1800						
Dec. 15	126.11.38,6	30, 0	47	1.19,4	53.47.54,6	53.47.21,3
16	126.11.35,7	30, 0	44	1.20,0		
24	53.47.22,1	29, 4	47	1.17,6		
25	126.11.29,7	29, 4	46	1.17,8		
26	126.11.30,7	—	43	1.18,3		
27	126.11.30,2	29,67	43	1. 9,0		
1801						
Dec. 13	53.48. 1,6	29, 6	35	1.20,4	53.48. 9,5	53.47.21,5
14	126.11.42,5	29, 8	35	1.21,0		
16	126.11.38,8	29, 3	35	1.19,7	53.48.11,5	53.47.21,8
17	126.11.36,4	29, 4	37	1.19,6		
18	53.48. 0,3	29, 7	34	1.20,8		
19	53.48. 1,0	30, 1	33	1.23,0		
	Mean	-	-	-	-	53.47.21,5

γ Draconis.

Day of the Month.	Observations corrected for Refraction.	Barom.	Therm.	Refraction.	Zenith Distance corrected for Refraction.	Mean Polar Distance for Jan. 1800. The Co-latitude 38°.45.′43″,0
1800	° ′ ″	Inches.	°	′ ″	° ′ ″	° ′ ″
Dec. 3	0.16.40,25			0,25	0.16.44,25	38.28.53,7
7	0.16.38,25					
8	179.43.10,75					
24	0.16. 1,75				0.16.37, 6	38.28.52,8
26	179.42.45, 6					
1801 Jan. 3	0.15.59,75					
13	179.43.46,25				0.16.31, 1	38.28.52,7
17	0.16.48, 5					
22	179.43.29, 5				0.16.27, 2	38.28.54,6
23	0.16.23, 8					
24	179.43.29, 5					
Feb. 6	0.16.18, 7				0.16.23, 0	38.58.54,7
13	179.43.32, 7					
	Mean	-	-	-	-	38.28.53,8

After the first part of this Paper went to the press, Dr. Maskelyne communicated to me some late corrections which Mr. Piazzi has made to his Catalogue. These having been adopted in the Tables which follow, the positive deviations do not now exactly equal the negative; but the correction required is very small. The Greenwich, Palermo, and Westbury observations were made about the same period, between 1800 and 1802, those of Armagh in the year 1797.

A Comparison of the Observations made at Greenwich, Armagh, Palermo, and Westbury, with a Catalogue deduced from the Mean of these, and of some other Observations made with different circular Instruments.

	Greenwich. January, 1800.		Armagh.		Palermo.		Westbury. Co-lat. 38°.45'.43",0.		Mean of all the Observations, reduced to Jan. 1800.
	° ′ ″		° ′ ″		° ′ ″		° ′ ″		° ′ ″
γ Draconis -	38.28.53,0	—0,8	38.28.52,5	—1,3	38.28.53,0	—0,8	38.28.53,8	+0,0	38.28.53,8
Capella -	44.13.21,5	+1,5	44.13.20,0	0.0	44.13.18,5	—1,5	44.13.18,5	—1,5	44.13.20,0
α Cygni - -	45.25.41,4	+2,6	45.25.38,0	—0,8	45.25.39,6	—0,8	45.25.37,0	—1,8	45.25.38,8
α Lyræ - -	51.23.41,1	+3,4	51.23.35,8	—1,9	51.23.37,8	+0,1	51.23.36,0	—1,7	51.23.37,7
Castor - -	57.41.14,0	0.0	*57.41. 8,0	——	57.41.14,0	0.0	57.41.14,0	0.0	57.41.14,0
Pollux -	61.30. 9,8	—2,2	*61.30. 3,8	——	61.30.12,2	+0,2	61.30.13,7	+1,7	61.30.12,0
β Tauri -	61.34.30,9	—1,6	61.34.31,0	—1,5	61.34.34,8	+2,3	61.34.33,7	+1,2	61.34.32,5
α Andromedæ	62.00.45,8	—1,2	62.00.43,7	—3,3	62.00.48,9	+1,5	62.00.50,0	+3,0	62.00.47,0
α Coronæ Bor.	62.36.10,5	+0,3	*62.36. 6,0	——	62.36.10,8	+0,6	62.36.13,0	+2,8	62.36.10,2
α Arietis -	67.29.20,1	—1,3	67.29.22,0	+0,6	67.29.22,7	+1,3	67.29.20,6	—0,8	67.29.21,4
Arcturus -	69.46. 7,8	—1,2	69.46. 9,7	+0,7	69.46.11,0	+2,0	69.46. 7,5	—1,5	69.46. 9,0
Aldebaran	73.54.16,6	—0,2	73.54.17,0	+0,2	73.54.18,0	+1,2	73.54.15,5	—1,3	73.54.16,8
β Leonis -	74.18.34,5	+0,8	74.18.32,7	—1,0	74.18.35,0	+1,3	74.18.32,5	—1,2	74.18.33,7
α Pegasi -	75.51.57,0	—2,0	75.51.59,8	+0,8	75.52. 1,0	+2,0	75.51.58,0	—1,0	75.51.59,0
γ Pegasi -	75.55.36,3	—0,7	75.55.36,2	—0,8	75.55.38,5	+1,5	75.55.37,0	0.0	75.55.37,0
Regulus - -	77. 3.35,1	+1,1	77. 3.30,7	—3,3	77. 3.37,5	+3,5	77. 3.34,0	0.0	77. 3.34,0
α Ophiuchi	77.16.54,0	+0,6	77.16.52,1	—1,3	77.16.54,0	+0,6	77.16.53,5	+0,1	77.16.53,4
α Aquilæ -	81.38.52,0	+1,5	81.38.49,3	—1,1	81.38.55,0	+4,5	81.38.51,5	+1,0	81.38.50,5
α Orionis -	82.38.30,8	—0,7	82.38.30,5	—1,2	82.38.33,0	+2,3	82.38.31,5	0.0	82.38.31,5
α Serpentis -	82.56. 1,2	—0,8	82.55.58,5	—3,5	82.56. 5,8	+3,8	82.56. 2,2	+0,2	82.56. 2,0
Procyon - -	84.16.17,4	—3,1	84.16.18,0	—2,5	84.16.22,0	+1,0	84.16.21,5	+1,0	84.16.20,5
α Ceti - -	86.42. 6,1	—1,5	86.42. 6,0	—2,2	86.42.10,8	+0,6	86.42.10,2	+2,0	86.42. 8,2
α Aquarii -	91.16.59,8	—3,2	91.17. 3,3	+0,3	91.17. 3,7	+0,7	91.17. 4,6	+1,6	91.17. 3,0
α Hydræ -	97.47.49,1	—1,5	97.47.47,5	—3,1	97.47.54,0	+3,4	97.47.53,0	+2,4	97.47.50,6
Rigel - -	98.26.28,8	—5,3	98.26.31,7	—2,4	98.26.35,5	+1,4	98.26.36,5	+2,5	98.26.34,1
Spica Virginis	100. 6.37,0	—3,0	100. 6.37,5	—2,5	100. 6.42,8	+2,8	100. 6.43,0	+3,0	100. 6.40,0
α Capricorni	103. 9. 3,2	—4,9	103. 9.12,0	+3,9	103. 9. 9,2	+1,1	103. 9. 8,0	—0,1	103. 9. 8,1
Sirius - -	106.26.56,3	—5,5	106.27. 3,8	+2,0	106.27. 5,0	+3,2	106.27. 2,0	+0,2	106.27. 1,8
Polaris - -	1.45.34,5	——	1.45.34,5	——	1.45.36,2	——	1.45.36,9	——	1.45.36,0

The observations marked * are omitted in the calculation.

The Greenwich Observations compared with those made by the circular Instruments, the Co-latitudes of the Places of Observation being previously corrected by Means of their positive and negative Deviations.

	Greenwich.		Armagh.		Palermo.		Westbury. Co-lat. 38°.45′.42″,8.		Mean of circular Instruments reduced to January, 1800.
γ Draconis -	38°.28′.53″,0	−0,6	38°.28′.53″,8	+0,2	38°.28′.52″,0	−1,6	38°.28′.53″,6	0.0	38°.28′.53″,6
Capella - -	44.13.21,5	+1,5	44.13.21,3	+1,3	44.13.18,5	−1,5	44.13.18,3	−1,7	44.13.20,0
α Cygni -	45.25.42,4	+2,6	45.25.39,3	+0,5	45.25.38,4	−0,4	45.25.36,8	−2,0	45.25.38,8
α Lyræ - -	57.23.41,1	+4,6	51.23.37,1	+0,6	51.23.36,8	+0,3	51.23.35,8	−0,7	51.23.36,5
Castor - -	57.41.14,0	+1,0	*57.41. 9,3	—	57.41.13,0	0.0	57.41.13,8	+0,8	57.41.13,0
Pollux -	61.30. 9,8	−2,5	*61.30. 4,2	—	61.30.11,2	−1,1	61.30.13,5	+1,2	61.30.12,3
β Tauri -	61.34.30,9	−2,1	61.34.32,3	−0,7	61.34.33,8	−0,6	61.34.33,5	+0,5	61.34.33,0
α Andromedæ	62.00.45,8	−1,7	62.00.45,0	−2,5	62.00.47,5	0.0	62.00.49,8	+2,3	62.00.47,5
α Coronæ B.	62.36.10,5	+0,5	62.36. 7,3	−2,7	62.36. 9,8	−0,2	62.36.12,8	+2,8	62.36.10,0
α Arietis -	67.29.20,1	−1,4	67.29.22,0	+0,5	67.29.21,7	+0,2	67.29.20,5	−1,0	67.29.21,5
Arcturus -	69.46. 7,8	−1,2	69.46.11,0	+2,0	69.46.10,5	+1,5	69.46. 7,5	−1,7	69.46. 9,0
Aldebaran	73.54.16,6	−0,3	73.54.18,3	+1,4	73.54.16,8	+0,1	73.54.15,3	−1,6	73.54.16,9
β Leonis -	74.18.34,5	+1,0	74.18.34,0	+0,5	74.18.33,5	+0,5	74.18.32,3	−1,2	74.18.33,5
α Pegasi -	75.51.57,0	−2,7	75.52. 1,0	+1,3	75.52. 0,8	+1,1	75.51.57,8	−1,9	75.51.59,7
γ Pegasi -	75.55.36,3	−1,9	75.55.37,5	−0,7	75.55.41,4	+3,2	75.55.36,8	−1,4	75.55.38,2
Regulus -	77. 3.35,1	+1,1	77. 3.32,0	−2,0	77. 3.36,0	+2,0	77. 3.33,8	−0,2	77. 3.34,0
α Ophiuchi	77.16.54,0	+0,8	77.16.53,4	+0,2	77.16.53,0	−0,2	77.16.53,3	+0,1	77.16.53,2
α Aquilæ -	81.38.52,0	+1,0	81.38.50,6	−0,4	81.38.53,5	+2,5	81.38.51,3	+0,3	81.38.51,0
α Orionis -	82.38.30,8	−0,9	82.38.31,8	+0,1	82.38.32,0	+0,3	82.38.31,3	−0,4	82.38.31,7
α Serpentis	82.56. 1,2	−1,1	82.55.59,8	−2,4	82.56. 5,2	+2,9	82.56. 2,0	−0,3	82.56. 2,3
Procyon -	84.16.17,4	−3,6	84.16.19,5	−1,5	84.16.21,0	0.0	84.16.21,3	+0,3	84.16.21,0
α Ceti - -	86.42. 6,1	−2,9	86.42. 7,3	−1,3	86.42. 9,8	+0,8	86.42.10,2	+1,2	86.42. 9,0
β Virginis -	87. 6.26,4	−2,0	87. 6.29,0	+0,7	87. 6.27,5	−0,8	not observed	—	87. 6.28,3
α Aquarii -	91.16.59,8	−4,3	91.17. 4,6	+0,5	91.17. 3,2	−0,9	91.17. 4,6	+0,5	91.17. 4,1
α Hydræ -	97.47.49,2	−3,0	97.47.48,8	−3,2	97.47.54,0	+2,0	97.47.53,0	+1,0	97.47.52,0
Rigel - -	98.26.28,8	−6,0	98.26.33,0	−1,8	98.26.34,5	−0,3	98.26.36,3	+1,5	98.26.34,8
Spica Virginis	100. 6.37,0	−3,8	100. 6.38,8	−2,0	100. 6.41,8	+1,0	100. 6.42,8	+2,0	100. 6.40,8
2 α Capricorni	103. 9. 5,2	−3,1	*103. 9.13,5	—	103. 9. 8,2	−0,1	103. 9. 7,8	−0,5	103. 9. 8,3
α Libræ -	105.11.55,6	−6,2	105.12. 0,9	−0,9	105.12. 2,7	+0,9	not observed	—	105.12. 1,8
Sirius - -	106.26.56,3	−7,2	106.27. 4,1	+0,6	106.27. 4,0	+0,5	106.27. 1,8	−1,7	106.27. 3,5
Antares -	115.58.14,4	−9,7	115.58.24,5	—	115.58.24,2	—	not observed	—	115.58.24,1
Fomalhaut	120.40.30,9	−9,3	—	—	120.40.40,2	—	not observed	—	—
Polaris - -	1.45.34,5	—	1.45.34,5	—	1.45.36,2	—	1.45.37,0	—	1.45.36,0

The stars marked * are omitted in the comparison.

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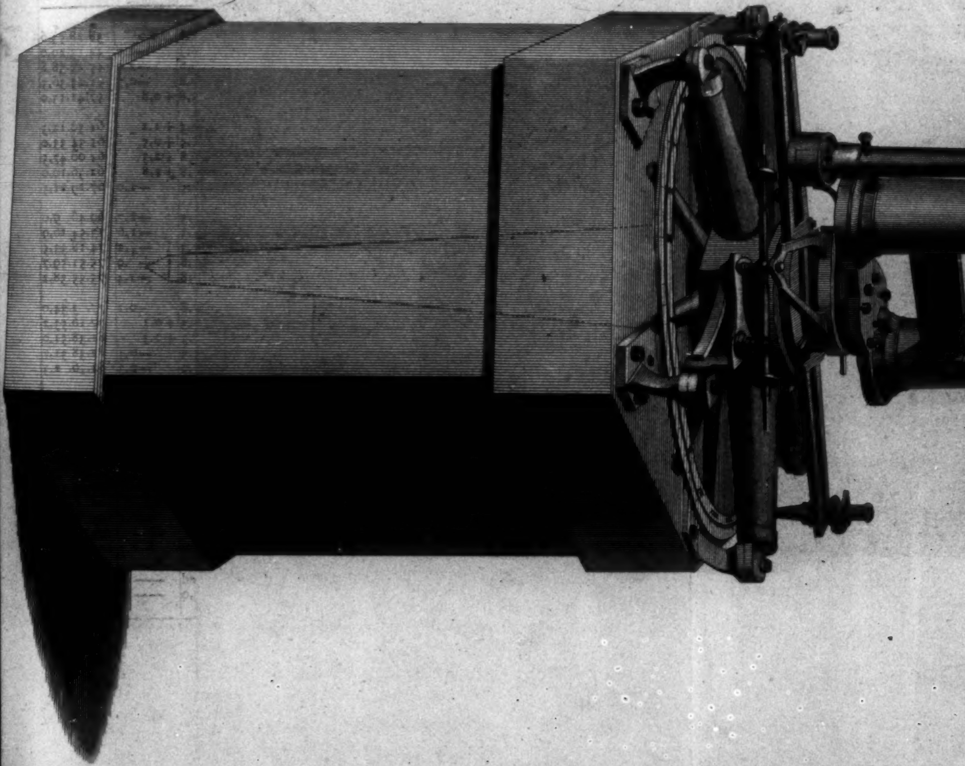

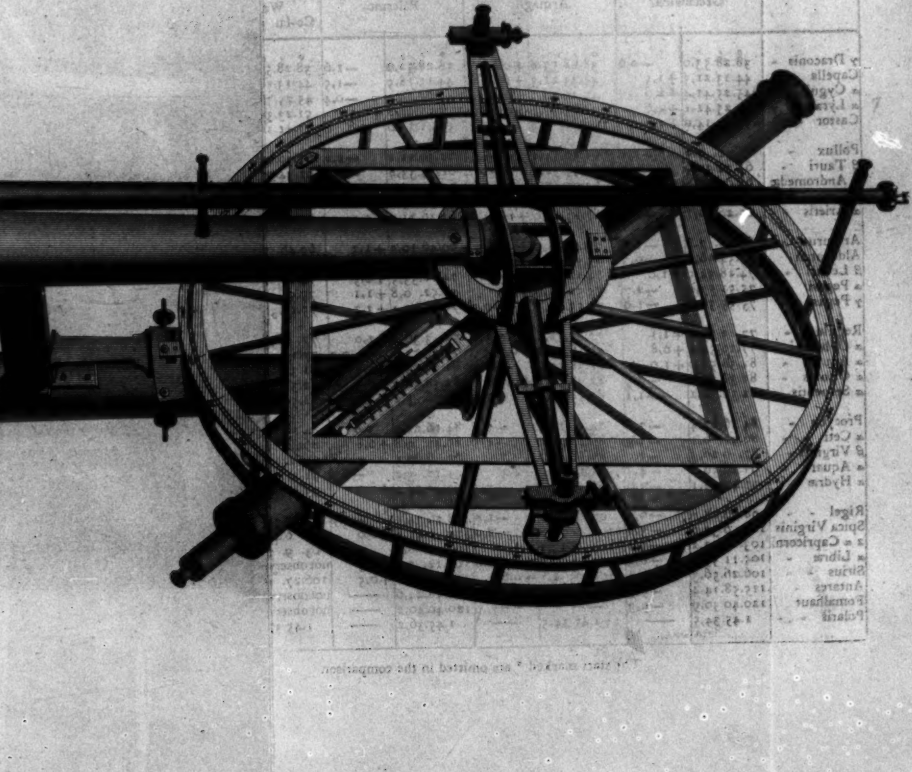

XXII. *Observations and Remarks on the Figure, the Climate, and the Atmosphere of Saturn, and its Ring.* By William Herschel, LL.D. F.R.S.

Read June 26, 1806.

My last year's observations on the singular figure of Saturn having drawn the attention of astronomers to this subject, it may be easily supposed that a farther investigation of it will be necessary. We see this planet at the period of its revolution round the sun in so many various aspects, that the change occasioned by the different situations in which it is viewed, as far as relates to the ring, has long ago been noticed; and Huygens has given us a very fine explanation of the cause of these changes.*

As the axis of the planet Saturn, as well as that of the ring, keeps its parallelism during the time of the revolution about the sun, it follows that there will be a sort of alteration, by which the ring is affected, and which produce certain alterations in the appearance of the planet; but the figure of the planet Saturn, though not exactly spherical, is very different from that of the ring; the changes occasioned by its different aspects will be so minute that only they can expect to perceive them who have been in the habit of seeing very small

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* See *Systema Saturnium*, page 73, where the changes of the ring are represented by a plate.

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As the axis of the planet's equator, as well as that of the ring, keeps its parallelism during the time of its revolution about the sun, it follows that the same change of situation, by which the ring is affected, must also produce similar alterations in the appearance of the planet; but since the shape of Saturn, though not strictly spherical, is very different from that of the ring, the changes occasioned by its different aspects will be so minute that only they can expect to perceive them who have been in the habit of seeing very small objects, and are furnished with instruments that will show them distinctly, with a very high and luminous magnifying power.

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* See *Systema Saturnium*, page 55, where the changes of the ring are represented by a plate.

If the equator of the planet Jupiter were inclined to the ecliptic like that of Saturn, I have no doubt but that we should see a considerable change in its figure during the time of a synodical revolution; notwithstanding the spheroidical figure occasioned by the rotation on its axis has not the extended flattening of the polar regions that I have remarked in Saturn. But since not only the position of the Saturnian equator is such that it brings on a periodical change in its aspect, amounting to more than 62 degrees in the course of each revolution, but that moreover in the shape of this planet there is an additional deviation from the usual spheroidical figure arising from the attraction of the ring, we may reasonably expect that our present telescopes will enable us to observe a visible alteration in its appearance, especially as our attention is now drawn to this circumstance.

In the year 1789 I ascertained the proportion of the equatorial to the polar diameter of Saturn to be 22,81 to 20,61,* and in this measure was undoubtedly included the effect of the ring on the figure of the planet, though its influence had not been investigated by direct observation. The rotation of the planet was determined afterwards by changes observed in the configuration of the belts, and proper figures to represent the different situation of the spots in these belts were delineated.† In drawing them it was understood that the shape of the planet was not the subject of my consideration, and that consequently a circular disk, which may be described without trouble, would be sufficient to show the configurations of the changeable belts.

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* Phil. Trans. for 1790, page 17.

† Ibid. for 1792, page 22.

Those who compare these figures, and others I have occasionally given, in which the particular shape of the body of the planet was not intended to be represented, with the figure which is contained in my last Paper, of which the sole purpose was to express that figure, and wonder at the great difference, have probably not read the measures I have given of the equatorial and polar diameters of this planet; and as it may be some satisfaction to compare the appearance of Saturn in 1789 with the critical examination of it in 1805, I have now drawn them from the two papers which treat of the subject; Fig. 1, Plate XXI. represents the spheroidical form of the planet as observed in 1789, at which time the singularity of the shape since discovered was unknown; and Fig. 2 represents the same as it appeared the 5th of May, 1805. The equatorial and polar diameters that were established in 1789 are strictly preserved in both figures, and the last differs from the first only in having the flattening at the poles a little more extended on both sides towards the equatorial parts. It is in consequence of the increase of the length of this flattening, or from some other cause, that a somewhat greater curvature in the latitudes of 40 or 45 degrees north and south has taken place; and as these differences are very minute, it will not appear extraordinary that they should have been overlooked in 1789, when my attention was intirely taken up with an examination of the two principal diameters of the planet.

The use of various magnifying powers in observing minute objects is not generally understood. A low power, such as

200 or 160, with which I have seen the figure of Saturn, is not sufficient to show it to one who has not already seen it perfectly well with an adequate high power; an observer, therefore, who has not an instrument that will bear a very distinct magnifying power of 500, ought not to expect to see the outlines of Saturn so sharp and well defined as to have a right conception of its figure. The quintuple belt is generally a very good criterion; for if that cannot be seen the telescope is not sufficient for the purpose; but when we have intirely convinced ourselves of the reality of the phenomena I have pointed out, we may then gradually lower the power, in order to be assured that the great curvature of the eye-glasses giving these high powers, has not occasioned any deceptions in the figure to be investigated, and this was the only reason why I mentioned that I had also seen the remarkable figure of Saturn with low powers.

In very critical cases it becomes necessary to calculate every cause of an appearance that falls under the province of mathematical investigation. For this reason I have always looked upon an astronomical observation without a date as imperfect, and the journal-method of communicating them is undoubtedly what ought to be used. For instance, when it is known that my last year's most decisive observation, relating to the singular figure of Saturn, was made the 5th of May, astronomers may then calculate by this date the place of Saturn and of the earth; their distances from each other, and the angle of illumination of the Saturnian disk; by these means we find the gibbosity of the planet in the given situation, and ascertain that the defalcation of light could not then amount to the one hundredth part of a second of a degree, and that consequently no error could arise from that cause.

I have divided the following observations into two heads, one relating intirely to the figure of the body of Saturn, the other concerning the physical condition or climate and atmosphere of the planet.

Observations of the Figure of Saturn.

In the collection of my observations on the planet Saturn, I have met with one made 18 years ago, which is perfectly applicable to the present subject, and is as follows:

August 9, 1788, 21ʰ 58′. 20-feet reflector, power 300. Admitting the equatorial diameter of Saturn to lie in the direction of the ring, the planet is evidently flattened at the poles. I have often before, and again this evening, supposed the shape of Saturn not to be spheroidical, (like that of Mars and Jupiter,) but much flattened at the poles, and also a very little flattened at the equator, but this wants more exact observations.

April 16, 1806. I examined the figure of the body of Saturn with the 7 and 10-feet telescopes, but they acted very indifferently, and, were I to judge by present appearances, I should suppose the planet to have undergone a considerable change; should this be the case, it will then be necessary to trace out the cause of such alterations.

April 19. 10-feet, power 300. The polar regions are much flattened. The figure of the planet differs a little from what it appeared last year. This may be owing to the increased opening of the ring, which in four places obstructs now the view of the curvature in a higher latitude than it did last year. The equatorial regions on the contrary are more exposed to view than they have been for some time past.

May 2. 10-feet, power 375. The polar regions are much flatter than the equatorial: the latter being more disengaged from the ring appear rather more curved than last year, so that the figure of the planet seems to have undergone some small alteration, which may be easily accounted for from our viewing it now in a different aspect.

The planet Jupiter not being visible, we cannot compare the figure of Saturn with it; but from memory I am quite certain that the flattening of the Saturnian polar regions is considerably more extended than those of Jupiter.

May 4. 10-feet, power 527. The equatorial region of Saturn appears to be a little more elevated than last year. This part of the Saturnian figure could not be examined so well then as it may at present, the ring interfering with our view of it in four places, which are now visible.

The flattening on both sides of the pole is continued to a greater extent than in a figure merely spheroidical, such as that of Jupiter; and this makes the planet more curved in high latitudes.

The planet being in the meridian, the equatorial shape of Saturn appears a little more curved than last year; but the air is not sufficiently pure to bear high powers well.

May 5. 10-feet, power 527. The air is very favourable, and I see the planet well with this power; its figure is very little different from what it was last year.

The polar regions are more extendedly flat than I suppose they would have been if the planet had received its form only from the effect of the centrifugal force arising from its rotatory motion.

The equatorial region is a little more elevated than it appeared last year.

The diameter which intersects the equator in an angle of about 40 or 45 degrees is apparently a little longer than the equatorial, and the curvature is greatest in that latitude.

The planet being in the meridian and the night beautiful, I have had a complete view of its figure. It has undergone no change since last year, except what arises from its different situation, and a greater opening of the ring.

May 9. Power 527. The air being very clear, I see the figure of Saturn nearly the same as last year; the flattening at the poles appears at present somewhat less; the equatorial and other regions are still the same.

May 15, 10h 30′. I examined the appearance of Saturn, and compared it with the engraving representing its figure in last year's volume of the Phil. Trans. The outlines and all the other features of this engraving are far more distinct than we can ever see them in the telescope at one view; but it is the very intention of a copper-plate to collect together all that has been successfully discovered by repeated and occasional perfect glimpses, and to represent it united and distinctly to our inspection. Indeed by looking at the drawings contained in books of astronomy this will be found to be the case with them all.*

The equatorial diameter of my last year's figure is however a very little too short; it should have been to the polar diameter as 35,41 to 32, which is the proportion that was ascertained in 1789, from which I have hitherto found no reason to depart.

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* For an instance of this, see TOBIÆ MAYERI *Opera inedita. Appendix Observationum. Ad Tabulam Selenographicam Animadversiones,* where the annexed accurate and valuable plate represents the moon such as it never can be seen in a telescope.

The following particulars remain as my last year's observations have established them.

The flattening at the poles of Saturn is more extensive than it is on the planet Jupiter. The curvature in high latitudes is also greater than on that planet. At the equator, on the contrary, the curvature is rather less than it is on Jupiter.

Upon the whole, therefore, the shape of the globe of Saturn is not such as a rotatory motion alone could have given it.

I see the quintuple belt, the division of the ring, a very narrow shadow of the ring across the body, and another broader shadow of the body upon the following part of the ring; and unless all these particulars are very distinctly visible we cannot expect that our instrument should show the outlines of the planet sufficiently well to perceive its peculiar formation.

May 16, 10^{h} 10′. The greatest curvature on the disk of Saturn seems to be in a latitude of about 40 degrees.

May 18. The difference between the equatorial and polar diameters appears to be a little less than the measures taken September 14, 1789, give it; but as the eye was then in the plane of the equator, and is now about 16 degrees elevated above it, we cannot expect to see it quite so much flattened at present.

June 3. The shadow of the ring falls upon the body of the planet southwards of the ring, towards the limb; it grows a little broader at both ends where it is upon the turn round the globe.

June 5. The planet Jupiter is not sufficiently high for distinct vision, and Saturn is already too low to use a proper magnifying power; but nevertheless the difference in the formation of the two planets is evident. The equatorial as well as polar regions on Jupiter are more curved than those of Saturn.

June 9. The air is beautifully clear, and proper for critical observations.

The breadth of the ring is to the space between the ring and the body of Saturn as about 5 to 4. See Fig. 3.

The ring appears to be sloping towards the body of the planet, and the inside edge of it is probably of a spherical or perhaps hyperbolical form.

The shadow of the ring on the planet is broader on both sides than in the middle; this is partly a consequence of the curvature of the ring which in the middle of its passage across the body hides more of the shadow in that place than at the sides.

The shadow of the body upon the ring is a little broader at the north than the south, so as not to be parallel with the outline of the body; nor is it so broad at the north as to become square with the direction of the ring.

The most northern dusky belt comes northwards on both sides as far as the middle of the breadth of the ring where it passes behind the body. It is curved towards the south in the middle.

I viewed Jupiter, and compared its figure with that of Saturn. An evident difference in the formation of the two planets is visible. To distinguish the figure of Jupiter properly it may be called an ellipsoid, and that of Saturn a spheroid.

Observations on the periodical Changes of the Colour of the polar Regions of Saturn.

In the observations I have given on the planet Mars, it has been shown that an alternate periodical change takes place in the extent and brightness of the north and south polar spots;* and I have there suggested an idea that the cause of the brightness might be a vivid reflection of light from frozen regions, and that the reduction of the spots might be ascribed to their being exposed to the sun.

The following observations, I believe, will either lead us to similar conclusions with respect to the appearance of the polar regions of Saturn, or will at least draw the attention of future observers to a farther investigation of the subject.

With high magnifying powers the objects we observe require more light than when the power is lower; this affords us a good method of determining the relative brightness of the different parts of a planet. The less bright object will be found deficient in illumination when the power exceeds what it will bear with ease. I have availed myself of this assistance in the observations that follow.

June 25, 1781. With an aperture of 6,3 inches I used a magnifying power of 460. This gave a kind of yellowish colour to the planet Saturn, while the ring still retained its full white illumination.

November 11, 1793. From the quintuple belt towards the south pole the whole distance is of a pale whitish colour; less bright than the white belts, and much less bright than the ring.

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* Phil. Trans. for 1784, page 260.

This has been represented in a figure which was given in the volume of the Phil. Trans. for 1794, page 32. It is to be noticed that the south pole of the planet had been long exposed to the influence of the sun, and the former polar whitishness was no longer to be seen.

Jan. 1, 1794. The south polar regions are a little less bright than the equatorial belt.

Nov. 5, 1796. The space between the quintuple belt and the northesn part of the ring is of a bright white colour.

This seems to indicate that the whiteness of the northern hemisphere of Saturn increases when there is less illumination from the sun.

May 6, 1806. The north pole of Saturn being now exposed to the sun, its regions have lost much of their brightness; the space about the south pole has regained its former colour, and is brighter and whiter than the equatorial parts.

May 15. The south polar regions of Saturn are white; those of the north retain also some whitishness still.

May 18. With a magnifying power of 527, the south polar regions remain very white. The equatorial parts become of a yellowish tinge, and about the north pole there is still a faint dusky white colour to be seen.

June 3. The south polar regions are considerably brighter than those of the north.

These observations contrasted with those which were made when the south pole was in view complete nearly half a

Saturnian year, and the gradual change of the colour of the polar regions seems to be in a great measure ascertained. Should this be still more confirmed, there will then be some foundation for admitting these changes to be the consequence of an alteration of the temperature in the Saturnian climates. And if we do not ascribe the whiteness of the poles in their winter seasons immediately to frost or snow, we may at least attribute the different appearance to the greater suspension of vapours in clouds, which, it is well known, reflect more light than a clear atmosphere through which the opaque body of the planet is more visible. The regularity of the alternate changes at the poles ought however to be observed for at least two or three of the Saturnian years, and this, on account of their extraordinary length, can only be expected from the successive attention of astronomers.

On the Atmosphere of Saturn.

June 9, 1806. The brightness which remains on the north polar regions, is not uniform, but is here and there tinged with large dusky looking spaces of a cloudy atmospheric appearance.

From this and the foregoing observations on the change of the colour at the polar regions of Saturn arising most probably from a periodical alteration of temperature, we may infer the existence of a Saturnian atmosphere; as certainly we cannot ascribe such frequent changes to alterations of the surface of the planet itself: and if we add to this consideration the changes I have observed in the appearance of the

Fig. 1.

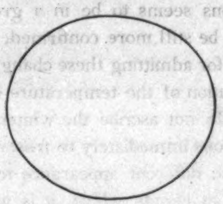


Fig. 2.

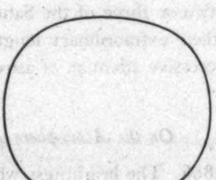
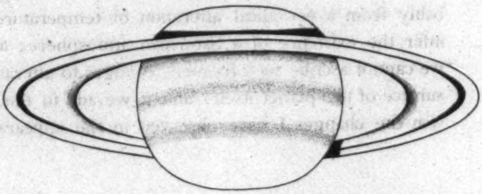


Fig. 3.



Basire sc.

belts, or even the belts themselves, we can hardly require a greater confirmation of the existence of such an atmosphere.

A probability that the ring of Saturn has also its atmosphere has already been pointed out in a former Paper.

Slough, near Windsor,
June 12, 1806.

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